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Edited by Jessica S. Horst and Janne von Koss Torkildsen

# INTERNATIONAL HANDBOOK OF LANGUAGE ACQUISITION

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# INTERNATIONAL HANDBOOK OF LANGUAGE ACQUISITION

*Edited by Jessica S. Horst and Janne von Koss Torkildsen*

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*To Ryan and James, JSH*
*To Leiv, Elsa and Trygve, JvKT*



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# PREFACE

Language may be the crowning glory of our species. Language is the system that enables us to communicate precisely and effectively with other people. Our linguistic skills allow us to express thoughts about the here and now, but also abstract ideas about what could have been if things had taken a different turn. We can communicate equally effortlessly about our understanding of the distant past and our hopes for the unknown future. These qualities make language a powerful tool to influence the minds of other people and to be influenced by them, thus facilitating cooperation, discussions and accumulation of knowledge across time and space. The potency of language makes it a driving force in communicative processes on all levels, from private social interactions to public discourse and technological advancement.

For many of us, language is so entrenched that we cannot help but take it for granted, just like our ability to breathe. But for many others language is far from second nature. Verbal communication, such as finding the right words, stringing them together or extracting the gist of what someone is saying, can be a struggle. There is great variability in proficiency with language both within and between individuals. Take the following examples from two children of the same ages, Elsa, who is learning Norwegian, and James, who is learning English:

ELSA 8 MONTHS: Mamma. *Mommy*.
ELSA 14 MONTHS: Se der. *Look there*.
ELSA 20 MONTHS: Barna leke grisen. *The children play the pig. (Intended meaning: the children play with the pig.)*
ELSA 23 MONTHS: Lekte med hun med den oransje bøtta. *Played with her with the orange bucket. (Intended meaning: I played with the girl with the orange bucket.)*
ELSA 29 MONTHS: En dag de skulle i fluefest, kom ulven og tok alle pastaene og gidde dem til mølleren. *One day when they were going to a fly-party, the wolf came and took all the pastas and gived them to the miller.*

JAMES 13 MONTHS: Mama.
JAMES 22 MONTHS: Ah . . . home!
JAMES 29 MONTHS: Eyes. Eyes. *(Intended meaning: the monsters have different eyes.)*
JAMES 34 MONTHS: All gone, coins.
JAMES 43 MONTHS: The steam is climbing up the sky.

As the examples above illuminate: language is not a pre-packaged ready-made skill that babies come equipped with at birth. Language is componential, and children use years to acquire its basic building blocks. Language develops.

But how do children progress from crying, cooing babies to articulate 5-year-old children? What underlying biological and cognitive processes enable such sophisticated language acquisition? What characterizes the developmental trajectory of the various dimensions of language, such as phonology, vocabulary, grammar and pragmatics? To what degree do individual children vary in their acquisition of these skills? And what everyday practices and activities drive language development forward? This handbook brings together the foremost researchers of language acquisition to answer these questions. The volume covers a wide range of topics central to language development from across several related disciplines, including psychology, linguistics, communication disorders, cognitive science and education. The study of child language has always been interdisciplinary, and we aim to support the cross-talk between disciplines. This handbook is meant as a resource for students, researchers, clinicians, teachers and others who would like to get an overview of current research on how children acquire language.

We chose to include the word "international" in the title as one of our aims was to include studies from children learning a variety of languages. Though parts of the literature on language development are still predominantly Anglo-centric, the past few decades have seen a marked increase in research on children learning languages other than English. This increase has enabled cross-linguistic comparisons and allowed us to draw together a more internationally oriented handbook.

Another aim was to present a handbook on language development with an applied focus. Specifically, we aimed to cover the everyday situations in which children in the twenty-first century learn their first words and how they continue to expand their language skills in various real world and digital contexts. In addition, we wished to bring individual differences to the forefront. While there are some eminent volumes targeting language and communication disorders exclusively, we sought to integrate studies of children who struggle to acquire language throughout the sections and chapters of this handbook. We believe that students of general language acquisition will benefit greatly from knowledge of individual differences in language acquisition.

The handbook is divided into four sections. Section 1 is devoted to the history of the field (Chapter 1) as well as the theoretical and physiological bases of language development, including the neural bases of language acquisition (Chapter 2), genetics (Chapter 3) and statistical learning (Chapter 4). We have also included some current and rapidly evolving research topics such as curiosity (Chapter 6), robotics (Chapter 5), the child's point of view (Chapter 7) and the role of sleep in language acquisition (Chapter 8).

In Section 2, each chapter focuses on a different dimension of what the child needs to learn to become a competent language user: the speech sounds (Chapter 9), the phonological templates (Chapter 10), the word-object associations (Chapter 11), the grammar (Chapter 14), the gestures (Chapter 12) and the pragmatics (Chapter 13). The penultimate chapter in this section (Chapter 15) presents evidence that children learning typologically different languages use different clusters of cues to learn simple and complex grammar. Consequently, research based on one language alone, such as English, cannot provide a universal account for the learning trajectories of these skills. Most children in the world learn to master the linguistic dimensions described above in more than one language. Thus, the final chapter in this section (Chapter 16) describes language acquisition in children exposed to two languages from birth.

The first chapter in Section 3 (Chapter 17) presents a review of the substantial individual differences in children's language development. The next four chapters focus on specific groups of children who have an atypical development of language or speech, including developmental language disorder (Chapter 18), speech sound disorders (Chapter 19), hearing loss (Chapter 20) and autism spectrum disorder (Chapter 21). We deliberately chose to not make this section the final section of the handbook, as is so common in many handbooks, because we feel it is important to include these chapters for their important theoretical and practical significance and not as an "afterthought" that not all children learn language in the same way.

The final section differs the most from previous handbooks on language development. Here we aim to go beyond presenting data from laboratory-based studies to shed light on how children learn to use language in everyday situations like interacting with books (Chapter 24) or digital media (Chapter 25), playing (Chapter 23) and listening to others' conversations (Chapter 22). These everyday settings are typically more complex, cluttered and noisy than the ones we set up for children in the laboratory, and thus require novel methods and analyses. In addition, the digital age has made language acquisition through reading and writing more prominent, even from the earliest stages of development. The two final chapters of the handbook outline how language acquisition happens through reading (Chapter 26) and writing (Chapter 27), including how development of literacy enables participation in modern society.

In curating this volume, we notice some trends that we think are positive developments that have led the field to new insights and that will continue to bring our research forward. While the focus in the field has predominantly been on how children use input from caregivers to learn language, we note an increased focus on child-driven learning through curiosity and information-seeking. We also notice recent studies using more robust empirical methods (e.g. improved statistical power and control over measurement error) and better transparency, including pre-registration and sharing of data sets and corpora. A valuable addition to the field in recent decades has been data from studies using on-line methods, such as eye-tracking, electrophysiological methods and functional magnetic resonance imaging, which provide information about the dynamics of language processing and learning as it happens, as well as the final outcomes. Similarly, advances in computing, specifically computational modeling, robotics and automatic analysis of speech, are helping us to answer research questions we never could have asked before. Recently, there has been an increased focus on studying language acquisition in real-life settings, and researchers have been able to complement the traditional lab-based studies using simple, artificial stimuli with studies of children in their natural environments and stimuli which better reflect the complexities of natural language. Another factor that has contributed to progress in our field is the addition of detailed studies on language acquisition in many new languages, though we still lack comprehensive scientific studies of language acquisition in most of the roughly 7,000 languages that are spoken in the world today.

Language is our crowning glory because it is not only extremely powerful as a communicative tool, but also immensely complex. While the developments described above have led to substantial progress in our understanding of language acquisition, there are still many areas in which researchers have only scraped the surface. This is reflected in the enthusiasm for greater interdisciplinary cross-talk and deeper understanding of real-world implications of language acquisition expressed across the chapters of this volume. We hope this handbook will serve as a springboard for posing new and better questions about how children break into language – which is possibly the most complex system that they will ever need to acquire.

*Janne von Koss Torkildsen and Jessica S. Horst*



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## SECTION 1

# Foundations of language acquisition



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# 1

# RESEARCH ON FIRST LANGUAGE ACQUISITION

## A brief history

*Eve V. Clark*

The study of language acquisition has a long history, dating as far back as the 7th century BC (Campbell, 2006), initially involving much speculation about how to find out what the original language was. As Campbell pointed out, these were pre-scientific studies, and scientific study of language acquisition only began with the systematic collection of observations, comparing them over time, to document the course of acquisition. With more detailed observations also came attempts to systematize the data, to track changes through different stages, and to see whether all children followed a similar path in learning a first language or languages. In this chapter, I first take up early diary studies, then turn to studies of children's first sounds in perception and production. Next, I take up the kinds of meanings they first attach to words, and how they build up a vocabulary. I then turn to attempts to write grammars for children at different stages as they combine single words into two-, three-, and four-word utterances. Next, I compare two major approaches to the process of acquisition: nativist approaches and interactive approaches, before considering some of the learning mechanisms that have been proposed. Finally, I raise the need for cross-linguistic data on acquisition and the paths children follow in acquiring different languages before researchers can draw a full picture of what is involved in acquiring a first language. I conclude with a few comments on current trends.

### Early days

The first records of children's early language came in the form of diary studies that also recorded many other aspects of development – motor, moral, and cognitive – alongside language. These diaries were mainly kept by researchers at the institutes of child development founded in the 1800s across Europe (Levelt, 2014). Later on, some diarists focused solely on their children's emerging language (e.g., Major, 1906, English; Stern & Stern, 1907/1928, German; Pavlovitch, 1920, Serbian/French; Leopold, 1939–1947, English/German; Grégoire, 1947–1949, French). These records contain quite detailed records of early language use, in particular of early sounds, early words, and early sentence structure, and therefore allow for some comparisons across children and languages.

The observational data in early diaries, though, present some shortcomings: the transcriptions of the time were orthographic rather than phonetic; there was little or no context for what children said, so their utterances were often simply listed without any context at all. Yet a number of

these studies were quite thorough, and so really constitute the first corpora we have access to. And the data still yield useful insights into some aspects of language development – for example, the kinds of sounds produced early on and the early meanings children assign to words (see, e.g., Jakobson, 1968; Clark, 1973).

Diary studies were largely superseded in the US in the 1900s by simple inventories of the words young children produce early on, and by records of vocabulary size used to assess language development in terms of number of words and average sentence-length at each age (e.g., Templin, 1957). However, since researchers did not focus on sentence structure per se, nor on the functions of different utterance-types, they paid little attention to how children used language, or how their usage changed with development over time.

In the 1960s, largely under the influence of Chomsky's innovative work in linguistics, research in the US shifted its focus to observations of the grammatical structure in children's utterances, and began to document the emergence of such structure as children went from one-word utterances to two-word combinations and then added further words and grammatical morphemes to mark such distinctions as person, number, case, and tense. These elements were all tracked as precursors to the acquisition of still more complex grammatical constructions. Researchers also began to do experimental studies of infants' ability to discriminate sounds from birth on, alongside observations of their early production of sounds in babbling, a precursor to their emerging skill in talking, as their first identifiable words appeared from age 1 onwards. Researchers also began to look at the kinds of meanings young children attached to their early words, and the extent to which these initially diverged from conventional adult meanings.

## First sounds

The study of the kinds of sounds infants produced, with their general order of emergence in production, was first considered systematically by Roman Jakobson (1968). He related the build-up of phonological contrasts in production by young children to the dissolution of language in adult aphasias. By drawing on observational records of production from numerous diary studies of different languages, Jakobson could propose a general order of acquisition in terms of contrasts for place and manner of articulation for categories of sounds.

Order of acquisition for contrasts in production:

1. [P-B] stops before [M] nasal
2. [T-D] stops before [N] nasal
3. [A] as first vowel sound

Possible early word-forms that could make use of this initial set of contrasts include:

*ba*, *pa*, *ma*, *baba*, *papa*, *mama*, *da*, *ta*, *na*, *dada*, *tata*, *nana*

More recently, researchers have looked closely at children's earliest productions of sounds, first in babbling, and then in early word-forms, to see whether babble predicts which sounds children will make use of first in early words. They documented what children could and

couldn't produce at ages 1 and 2, and which sounds appeared easy versus hard for production. For example, children can typically produce stops – [t~d, p~b, k~g] – before fricatives and affricates – [f~v, s~z, tʃ~dʒ] – and before clusters – [st-, sn-, sl-, ʃr-, fl-, str-, br-, bl-]. In early attempts at clusters, they typically omit elements like liquids, [l] and [r], and glides, [j] and [w], as well as [s] before consonants, only adding the missing [s] later on. Researchers also documented the types of sounds that are generally produced late in acquisition, as well as noting individual differences among children (e.g., Ferguson & Farwell, 1975; Ingram, 1989; Labov & Labov, 1978; Smith, 1973; Stoel-Gammon, 2011).

In the early 1960s, researchers also began to make systematic experimental studies of the distinctions among sounds that infants could discriminate from soon after birth. They examined different classes of sounds, focusing on infants' growing ability to discriminate place and manner of articulation (e.g., /ba/ vs. /ga/, or /ba/ vs. /pa/) as well as their ability to distinguish some intonational contours (e.g., rising vs. falling on the same syllable). This work revealed that, like adults, infants displayed categorical perception at a very early age (see Eimas, Siqueland, Juscyk, & Vigorito, 1971; Jusczyk, 1997; Nazzi, Bertoncini, & Mehler, 1998; Chapter 10, this volume).

The major issue for infants, though, is breaking into the actual speech stream. How do they segment adult speech into units? Essentially, they need to be able to recognize recurring sequences of sounds and treat them as chunks that, later on, they can associate with some consistent meaning. Adult talk with infants and young children should help here since adults talking to young children typically produce rather short utterances, with pauses in between, and repeat them frequently, especially those associated with daily routines like dressing, changing, eating, sleeping, and washing (e.g., Ferrier, 1978). In other words, adults' child-directed speech helps highlight word and phrase boundaries, at the beginnings and ends of utterances, from early on. For example, adults often use fixed frames as they talk with very young children (e.g., *There's a* ___, *Look at the* ___), another way of signaling the initial boundary for the word that follows. And since that word typically presents new information, it is highlighted with heavier stress (Fernald & Hurtado, 2006; Clark, 2010; Grassman & Tomasello, 2010). By 8 to 9 months old, infants appear sensitive to legal sequences of sounds that begin and end syllables in the language around them, and they will listen longer to legal than to illegal sequences (Friederici & Wessels, 1993; Morgan & Saffran, 1995). In short, they begin to identify recurring sequences of sound from early on, and these sequences, stored in memory, are then available for attaching meanings.

## First meanings

A few very early meanings are tied to everyday routines like *hi*, or *bye-bye*, plus a wave of the hand, as greetings. In general, though, many early word meanings in young children differ from conventional adult meanings in being over-extended. For example, children produce a word like *doggie* not only to refer to dogs, but also to cats, squirrels, sheep, and horses. Children rely here mainly on similarities of shape, so the initial meaning attached to *doggie* could perhaps be characterized as something like "four-legged mammal-shaped entity" (Clark, 1973). Some researchers argued that over-extensions were evidence of failures to discriminate the relevant categories, but others pointed out that over-extensions could simply be the outcome of a communicative strategy, where children opt for the "best word available" in their current repertoire in order to refer to the entity in the current focus of attention. One test of this is to look at how children understand the word *dog* or *doggie* when they over-extend it in production. If they interpret it in an

adult manner, this would be evidence for a communicative strategy. And indeed, over-extenders choose pictures of dogs over other mammals when asked "show me the dog". In short, they do not over-extend in comprehension even when they are doing so in production (Thomson & Chapman, 1977; Gelman, Croft, Fu, Clausner, & Gottfried, 1998).

This propensity for over-extending early words has been widely observed across many languages, in diary studies, and it even turns up in the cries of young vervet monkeys (Cheney & Seyfarth, 1988). Researchers have estimated that young children over-extend a third or more of their early words at a stage when they have up to 75 words in production (Rescorla, 1980). But as they add new words in production, they narrow down over-extensions and, with more exposure, begin to adhere more closely to adult conventions on word use (Leopold, 1939–1947; Barrett, 1978).

When children encounter new words, they have to assign some meaning to them. Their initial assignments have been called "fast mapping", assignments that make some sense in the immediate context where they first hear a new word used. Later, they hear further uses of the same word and can refine and add to whatever initial meaning they assigned. Getting to the conventional adult meaning, though, can take a long time. In assigning meanings, children appear to rely on the same pragmatic principles as adults: they assume that each word has a conventional meaning and that whenever there is a difference in form, there must be some difference in meaning. In short, words contrast in meaning. Over and above that, they assume that participants in a communicative exchange are trying to cooperate (see Clark, 1990, 1993; Grice, 1989).

Children build up their vocabulary quite steadily in production, but comprehension always leads (for adults too). By age 6, children acquiring English are estimated to understand about 14,000 words. From then on, they add about 3,000 more words a year in school, so by adulthood, they are estimated to understand between 50,000 and 100,000 words. Finally, as they add words, they organize them into semantic domains or fields of terms related in meaning (Clark, 1995, 2018b; Rescorla, 1981).

When children lack a word for what they want to talk about, from very early on they fill such gaps with coinages, drawing on known words and affixes to construct terms to convey the relevant meaning in context. For example, as young as age 2, children acquiring English use nouns as a source for new verbs, much as adults do (e.g., *it's flagging*, of a flag blowing in the wind; *he's pianoing* "playing the piano"), but they don't always observe all the pragmatic restrictions in this process. They also construct new compound nouns to identify subcategories (a *fire-dog* "a dog found at the site of a fire", *chimney-smoke* vs. *car-smoke* "exhaust", a *plate-egg* vs. a *cup-egg* "fried" vs. "boiled"); and they form new words through derivation, adding affixes to a known root to convey a new meaning (a *reacher* "someone who can reach a long way", a *cooker* "a cook", a *trumpetist* "a trumpeter", and so on) (Clark, 1982, 1993, 2014). Children typically adopt the most productive options first in constructing new words in their language. They later replace these as needed by the conventional terms. This is because many child coinages are not legitimate from an adult point of view since they stand in for existing words with the very same meanings. Existing words in a language pre-empt such coinages (Clark & Clark, 1979; Clark, 1993).

In summary, children assign and use meanings rather consistently from the start. They observe the same pragmatic principles as adults when they use language. They follow adult usage as a guide to conventional meanings and assume that words that differ in form differ in meaning. But they may take months, or even years, to acquire something like the full conventional meanings of many terms. As a result, they have to rely on whatever partial meanings they have acquired so far. Since these generally overlap to some extent with the intended adult meanings, children can communicate quite effectively, even when they have yet to acquire the full adult meaning of many of their words (see further Clark, 1993; P. Bloom, 2000).

## Early syntax

In the mid-1960s, research in psycholinguistics, including research on first language acquisition, became strongly influenced by the revolution in linguistics introduced by transformational grammar (Chomsky, 1965). This approach to language, or rather to the syntax displayed in language, appeared to offer a metric of cumulative complexity and hence a way of measuring development. It also raised the question of how children's "grammars" might be related to an adult grammar of the language being acquired. This is what led to increased emphasis on the structure of young children's utterances as they moved on from single words to two-word combinations, usually towards the end of the second year, and then on to even more complex constructions, and how to capture these changes in child grammars for each stage.

One immediate issue was where syntactic categories like Noun and Verb came from, and whether children's early uses of apparent nouns and verbs in one- and two-word utterances should be credited with already instantiating those parts of speech. Braine (1963) proposed that researchers should instead make distributional analyses of children's utterances in order to track how they discover such categories as Noun. But at this point, researchers did not consider the kinds of distributional information available in adult speech (for later research, see Mintz, 2003). Roger Brown and his students took such grammatical categories for granted, relying on the Chomskyan claim that they were innate, built-in for humans as part of their capacity for language. This abstract underlying information, it was proposed, would allow children to discover the relevant grammatical categories for constructing sentences in whatever language they were exposed to (see Pinker, 1984/2009).

At the same time, Brown did recognize the potential importance of adult-child exchanges, for example, in his work on the acquisition of wh-question forms (Brown, 1968). In much of his research, though, Brown focused primarily on notions of cumulative complexity and order of emergence in the grammars he wrote for children acquiring English (Brown & Bellugi, 1964; Brown, 1973), as did Bowerman (1973) for children acquiring Finnish. The main emphasis in this research was on the grammatical form of children's utterances – the words they chose, the way they ordered them, and any inflections they added. However, researchers in general paid little or no attention to the conversational setting or the physical context of children's early utterances, and, initially, they also paid relatively little attention in their analyses to children's intended meanings.

However, some researchers realized that one needed to keep track of contextual information in order to interpret children's two-word utterances. The same utterance – *Mommy sock* (from Kathryn, aged 1;9), for example – could have quite different meanings depending on the context the child produced it in: for example, "that's mommy's sock", a claim about possession, or "mommy is putting on my sock", a description of an event (L. Bloom, 1970). Including the physical context of an utterance in order to identify the intended meaning led later researchers to take into account the overall conversational context as well, hence attending to what both the adult and the child were contributing to a conversational exchange.

What adults say, and how they say it, must clearly play some role as they talk with their children. Lois Bloom and her colleagues (1976, 1980) recognized that what adults say to their children may be critical for what children learn when. From the 1980s onwards, researchers began to document the nature of adult speech with children in detail, showing how it changed as children got older and developed more language (see Snow & Ferguson, 1977; Gallaway & Richards, 1994; Arnon, Casillas, Kurumada, & Estigarribia, 2014).

The range of syntactic constructions studied in children's speech in the 1970s and 1980s, and hence the range accounted for in their early grammars, was rather limited. Once past the

two-word stage, researchers tracked the emergence of complement structures (I want *to go outside*), wh-questions (*where* is he going?), and relative clauses (the man *who was in the barn*), and they looked at some aspects of pronominal co-reference within and across clauses (*the man* knocked and then *he* opened the door) (e.g., Bloom, Tackeff, & Lahey, 1984; Bloom, Lifter, & Hafitz, 1980; Kidd, Lieven, & Tomasello, 2010; Brandt, Kidd, Lieven, & Tomasello, 2009; Rowland, Pine, Lieven, & Theakston, 2003; Lust et al., 1994; see also Chapter 14, this volume).

Early claims about the point of acquisition for a construction were sometimes based on the use of a single verb that took a complement (e.g., *want*), with little or no evidence for any rule-based generalizations. But, as Lieven and her colleagues later showed, children base their early learning of constructions first on specific lexical items and phrases, and only after adding further items to a construction do they begin to generalize (e.g., Pine & Lieven, 1993; Lieven, Pine, & Baldwin, 1997).

The insight that children typically begin with fixed formulae, or routine uses of words and phrases, only later analyzing these into their parts and identifying their roles in each construction-type, marked a major step forward in studies of syntactic acquisition (see Lieven, Salomo, & Tomasello, 2009; Bannard & Lieven, 2012; Tomasello, 2003). In their studies of acquisition, these researchers tracked children's earliest uses of specific constructions and how long it took children to substitute in a different noun, verb, or article, say, and so display the start of generalization for a phrase or a construction. For example, children may at first use only one article with a specific noun (*the* cup, *a* spoon), a specific verb only with one object noun (throw *ball*, drink *milk*), and in general rely extensively on fixed formulae at the two-word stage (e.g., Tomasello, 1992; Lieven et al., 1997; Matthews & Bannard, 2010). Attention to such fixed routines in speech also appears to help children produce conventional irregular forms in lieu of over-regularizations, e.g., *mice* instead of *mouses*, or *fell* instead of *falled* (e.g., Arnon & Clark, 2011; Arnon, McCauley, & Christiansen, 2017).

In short, researchers have found extensive support for construction-based usage in children's early syntactic acquisition (see Clark & Kelly, 2006; Goldberg, 1995, 1999; Goldberg, Casenhiser, & Sethuraman, 2004). This approach takes account of the forms and constructions in adult speech, and shows that children's uptake of syntactic constructions depends in part on the frequency of the forms they are exposed to (see, e.g., Estigarribia, 2010). Generalizations that can be captured in the form of rules emerge only some time later.

## Nativist approaches

In the 1960s, as part of his new look at syntactic structure in language, Chomsky proposed that humans must draw on an innate "language acquisition device" in acquiring a first language. At the same time, children must still somehow identify the relevant sound system and words in whatever language they are exposed to and, in doing this, identify which words belong to which syntactic categories. The assumption about grammatical structure here was that children simply needed exposure to a language in order to map relevant words to such syntactic categories as Noun, Verb, Preposition, and Adjective. Exposure alone would trigger acquisition, given the presence of innate grammatical categories and a "selection bias" for identifying the relevant language family (e.g., Chomsky, 1981; Borer & Wexler, 1987; Hyams, 2012; see also Culicover, 1999). These factors in turn would allow children to set various parameters (e.g., the need for an overt subject in English, compared to languages where the subject is identified in the verb inflections that also mark number and tense, say, as in Spanish). Such parameters help identify the grammar relevant to a specific language. However, the number of parameters identified using this approach remains limited, and their overall role in the acquisition of grammar is still being explored.

In his original proposal about an innate "language acquisition device", Chomsky (1965, 1986) argued that grammatical aspects of language had to be innate because children received no negative evidence about errors, and were exposed to an impoverished version of the language, characterized as poverty of the stimulus. Yet despite this, children acquired the adult language. These two dogmas, no-negative-evidence and poverty-of-the-stimulus, were regarded as central to claims about innateness, and have been consistently endorsed by theoretical linguists ever since. However, in neither case – no negative evidence (i.e., no feedback following child errors during acquisition) and poverty of the stimulus (exposure to an incomplete version of the adult language) – have these claims been backed up by any empirical evidence. Indeed, there is strong evidence against both of them.

Children receive extensive feedback on errors, with adults frequently supplying the conventional word-form or construction in the next turn as they make sure they have understood what the child intended to say. This rather thorough form of negative evidence is contingent on the errors children make (see, e.g., Chouinard & Clark, 2003; Clark & de Marneffe, 2012; Lustigman & Clark, 2019; Farrar, 1992; Saxton, Kulcsar, Marshall, & Rupra, 1998; Strapp, 1999). Adults also supply extensive information about the constructions available in the language as they talk with their children, and thereby supply positive information directly relevant to the analysis and acquisition of specific constructions. This exposure, not surprisingly, is paced to what children appear to understand, hence the absence of certain constructions in talk to very young children (see Snow & Ferguson, 1977; Pullum & Scholz, 2002; Sholtz & Pullum, 2002, 2006).

Another theoretical issue central to innatist arguments is the notion of a *critical period* for first language acquisition – a window during which children must acquire their first language if they are going to do so. Once past this window, the acquisition of language in native-like form is no longer possible. Such a critical period was estimated to end around age 12 or so, but it may in fact end considerably later (Lenneberg, 1967; Penfield & Roberts, 1959; Hartshorne, Tenenbaum, & Pinker, 2018). The notion of a critical period (now generally called a sensitive period by biologists) has been tied to various stages of brain development, but many changes take place in the human brain up until early adulthood, so it has been difficult to identify which changes actually affect the general process of first language acquisition. However, brain damage in the early years, compared to later on, does result in different outcomes for language acquisition and recovery. With damage incurred early, children may recover or re-acquire language. But left-hemisphere damage incurred later on is more problematic for the retention or re-acquisition of language, in both comprehension and production (Lenneberg, 1967; Curtis, 1977; Vicari et al., 2000; Stiles, Reilly, Paul, & Moses, 2005; Kuhl, 2010).

The notion of a critical period also has an impact on second language acquisition. A second language acquired in earlier childhood, before age 12 or so, is typically acquired much like a first language, but when people acquire further languages later on, in adulthood, they rarely attain native-phonology even when they become fluent speakers (Robinson & Ellis, 2008; Krashen, 1981). This is in contrast to early and late childhood bilinguals who typically acquire native-phonology and fluency in both languages (de Houwer, 2009). At the same time, of course, both bilinguals and second language speakers may have differing areas of expertise (with the relevant vocabulary) in each language, something that can change with age, location (moving to another country), and professional commitments (Grosjean, 1982).

## Interactionist approaches

The interactionist approach to acquisition grew out of the recognition that how, and how often, adults talk with their children has a direct effect on the process of acquisition. Recognition of

this relationship began with Lois Bloom's research on the acquisition of syntax and inflectional morphology (see, e.g., Bloom, 1980; Bloom et al., 1976; Bloom et al., 1980; Bloom et al., 1984). It was followed up by extensive research on how adults talk with children, and how this changes as children acquire more language (Snow & Ferguson, 1977; Gallaway & Richards, 1994).

More recently, researchers have also begun to look at how adults respond to children's errors, and the kinds of feedback about conventional forms they offer in doing this, typically in the very next turn. This feedback is immediate, and is generally offered with question-intonation, so children can confirm (yes that's what I meant), or reject, the adult interpretation being offered in this way. This type of negative feedback is stable over errors made in pronunciation, morphology, syntax, and lexical choice (Chouinard & Clark, 2003; Clark, 2018a). Conversation, of course, also offers extensive further exposure to language, just as book-reading and other activities that make use of language do.

Adults offer positive feedback in the form of confirmations of what children have contributed, and in general continuations on the same topic. And they also do this in contexts where children's contributions may be ambiguous, as when children acquiring French offer forms like /sotɛ/ that could be past participles (*sauté* "jumped") or infinitives (*sauter* "to jump"). Here adults attend to the physical context and, in the case of events that have already occurred, for instance, offer a construction that includes an auxiliary verb and past participle, as in *oui, il a sauté* ("yes, he jumped/has jumped"). But when the action instead is being anticipated, they offer a modal and infinitive construction instead, as in *il veut sauter* "he wants to jump" or *il va sauter* "he's going to jump" (Clark & de Marneffe, 2012). Parents here are deliberately clarifying what children appear to intend in context. Much the same appears to be going on when children acquiring Hebrew produce opaque verb forms with no inflection added: parents gloss the forms in context in the next turn, and offer 1- and 2-year-olds conventionally inflected verb forms for the meanings apparently intended (Lustigman & Clark, 2019).

In short, the to-and-fro of conversation appears crucial to the process of acquisition. Adults, often parents, consistently check up on what children mean when they make errors. They do this by offering a reformulation, in conventional form, of the meaning apparently intended. They also offer reformulations when children's utterances are opaque, lacking inflections or syntactic structure that might clarify the meaning intended. And they talk together with children about daily activities, needs, intentions, and actions. As a result, children receive still more exposure to the appropriate conventional language for expressing specific meanings.

## Learning mechanisms

Both general approaches, innatist and interactional, assume certain learning mechanisms. On the innatist side, researchers expect that children need to learn the phonology and the lexicon of the language, even if the morphosyntax is taken care of by an innate language acquisition device. How this would be done remains unspecified. On the interactional side, children are viewed as needing to learn all the elements of the language they are being exposed to. What general factors must play a role here?

First, one can argue for the ability to identify entities as the same or different. This basic discrimination allows infants and children to classify sounds and sound sequences, as well as larger chunks of linguistic material, into categories. And there is extensive evidence, from early on, that infants and young children make use of this ability. Eight-month-old infants, for example, can learn sequences of sounds with recurring chunks, and distinguish those sequences from sequences where the original chunks have been segmented at different points to produce new chunks (Saffran, Aslin, & Newport, 1996). Infants attend to similarity and difference, and to

statistical properties of the sequences heard initially. This information they store in memory, and then make use of, as they later assign meanings to particular sequences.

Very young children, just like adults, understand more than they can produce. The asymmetry between comprehension and production itself plays an important role in the process of acquisition. Children store adult forms and their meanings in memory, and later use these stored forms as templates in monitoring their own productions. So when they detect mismatches between forms stored in memory and forms they are attempting to produce, they can make spontaneous self-repairs (Clark, 2016; Levelt, 1989).

Attention to recurring sequences plays a long-term role in learning: children attend to distributional patterns in the language they hear, and thereby come to distinguish nouns from verbs, for example, with some reliability, even when they don't yet know the meanings of many of the words in question (Mintz, 2003). They latch onto and make use of frequently occurring sequences of words and phrases. They store these in memory and produce them "ready-made" when needed (Matthews & Bannard, 2010). This ability plays a role, for example, in the acquisition of irregular forms when these appear in such frequently occurring frames as "three blind mice" (Arnon & Clark, 2011). Overall, attention to the statistical properties of the language they hear helps them both store and retrieve relevant words and phrases later on (see further Raviv & Arnon, 2018; Christiansen & Chater, 2017).

Children, like adults, rely heavily on assumptions about communication during acquisition and beyond. Primary among these is the assumption that speakers intend to be informative in what they say. Children, as addressees, must therefore make pragmatic inferences that make sense in context on each occasion, especially in potentially ambiguous contexts. Their inferences in contexts are licensed by speakers, and these help children both assign initial meanings for new words and select the relevant meaning when several are possible (Clark, 1988, 1990; Clark & Wong, 2002; Frank, 2014; Frank & Goodman, 2014). In effect, children appear to rely on probabilistic inferences in context, choosing the most reasonable on each occasion, as they interpret what the speaker has just said. In doing this, they rely on knowledge about words already acquired, making use of any conventional meanings they know. And they attend to contrast, taking each difference in word-form as signaling a new meaning that contrasts with those already acquired (Clark, 1993).

In effect, as children attend to what the speaker seems to be talking about, they try to identify the intended referent on each occasion and, over time, combine their selections with slow associative learning for the term used, until they can access that term whenever they see a further instance of that category (see also Chapter 11, this volume). Such learning allows young children to build a repertoire of words and expressions they can understand and, later on, produce, when they wish to talk about instances of the relevant categories (McMurray, Horst, & Samuelson, 2012; Perry, Samuelson, Malloy, & Schiffer, 2010). This general view of learning, of course, depends on the pragmatic inferences involved in identifying speaker intentions. In doing this, children follow general principles of communication (H. Clark, 1996; Grice, 1989; Simon, 2000). This in turn can result in children acquiring those terms and expressions that are used more frequently earlier than they do less frequent terms and expressions. They therefore become able to retrieve more frequent terms more readily than less frequent ones. This in turn affects both the speed with which child speakers plan and produce their utterances, and the readiness with which child addressees interpret what they hear from others.

## Cross-linguistic studies

Finally, from the era of diary studies on, researchers have been concerned about the patterns of acquisition in different languages, both with in-depth studies of single languages, and with

studies of children growing up bilingual. Early diaries covered the acquisition of a variety of languages, including Dutch, English, French, German, Hungarian, Italian, Polish, Russian, and Spanish, with a few diaries documenting the course of acquisition for two languages at once (see further Levelt, 2014). Later on, researchers reported on cross-linguistic research for a variety of languages ranging from West Greenlandic to Finnish, Hebrew, French, German, Hungarian, Japanese, and Mandarin (Slobin, 1985–1997). The impetus to consider cross-linguistic data on first language acquisition was also supported by the establishment of CHILDES, an archive of longitudinal and cross-sectional audio- and video-recordings, with their transcriptions, from children acquiring different languages (MacWhinney & Snow, 1990; Slobin, 1985–1997).

Children are able to learn any language, regardless of structure. Indeed, initial analyses and comparisons across languages led Slobin to propose that children rely on general "operating principles" that they apply to whatever language they are exposed to. This accounts for similarities across languages in the early stages of acquisition, as well as differences later on as children identify more language-specific properties. Children must therefore approach language quite flexibly while also displaying some similarities early in acquisition (Bowerman, 2018).

Cross-linguistic studies highlight both similarities, as in the general functions of two-word utterances in languages as different as Samoan and French, or Finnish and Mandarin, and differences in the patterns of acquisition observed for different types of language (Clark, 2016; Slobin & Bowerman, 2007). Children appear to start from a very similar basis for one- and then two-word utterances, but may then diverge considerably. Some languages are highly inflected, with elaborate case systems as well as verb inflections for person, number, and gender, as well as aspect, mood, and tense (e.g., Finnish, Polish). Others have minimal inflectional systems (e.g., Cantonese, Mandarin, English). Some inflectional systems are highly regular (e.g., Hungarian, Turkish) while others include considerable irregularity (e.g., Russian). Others still rely heavily on word order to convey meanings otherwise expressed with inflections or grammatical morphemes (cf. definiteness in Finnish).

Overall, constructions that are complex in some languages may be easier in others for acquisition. Consider relative clauses in English versus Turkish. In English, the relative clause follows its head, the noun it is modifying (the boy *who was sitting on the swing* . . .), but in Turkish, the relative clause must be placed initially, before its head (*who was sitting on the swing*, the boy. . .). As a result, children acquiring English begin to attempt relative clauses at around age 2, while children acquiring Turkish do so only later, from around age 7 or so (Chapter 15, this volume). And there are trade-offs within, as well as across, languages: no one language appears to be uniformly "easy" or uniformly "hard" to acquire. Rather, the relative complexity of factors like phonological structure, inflections, and word order within a language can all affect the speed with which children master specific adult conventions in that language. Comparisons across languages therefore remain crucial in identifying what is easy versus hard for children by comparing the course of acquisition for typologically different languages.

## Recent trends

More recent trends in research on language acquisition have focused on identifying the learning mechanisms children rely on, modeling the effects of such factors as frequency in the adult language children hear, and tracking the kinds of feedback, negative and positive, that children receive during the early stages of acquisition (e.g., McMurray et al., 2012; Frank, 2014; Meylan, Frank, Roy, & Levy, 2017; Mintz, Li, & Wang, 2014; Kidd, Lieven, & Tomasello, 2010; Chouinard & Clark, 2003). Researchers have also taken up issues of planning for speaking and how young children manage this when their skills are still limited, the timing of utterances as one

speaker yields to another, or takes over from another, and how accurately young children identify words that they cannot yet say themselves (e.g., Casillas, Bobb, & Clark, 2016; Jusczyk, 1997; Friederici & Wessels, 1993).

Researchers also continue to examine the relative contributions of gesture and speech in communication, the role of body stance and positioning, and the ways people interact with nods, gaze, and hand gestures in coordination with what they say (Bangerter, 2004; Bonvillian, Garber, & Dell, 1997; Gullberg, de Bot, & Volterra, 2008; Goldin-Meadow, 2014; Gullberg & Kita, 2009; Cartmill, Rissman, Novack, & Goldin-Meadow, 2017). These all play a role in the achievement of joint attention, a central element in communicative exchanges (see Tomasello, 1995; Yu & Smith, 2013). They are also studying in more detail the acquisition of phonology, morphology, semantics, constructions, and pragmatics for particular languages, and for particular varieties within languages (e.g., Bowerman & Brown, 2008; Bavin & Stoll, 2013; Stoll et al., 2012; Smith, Durham, & Fortune, 2009).

Another area that is expanding is the relation of speech and communication to specific aspects of brain development. Researchers have studied lateralization for newly acquired words, for example, in 1-year-olds and in adults (Mills, Coffey-Corina, & Neville, 1997; Borovsky, Kutas, & Elman, 2010). And they have begun to look at how language becomes organized in the brain with development (Mills et al., 2004; von Koss Torkildsen et al., 2009; Meltzoff, Kuhl, Movellan, & Sejnowski, 2009; Conboy, Brooks, Meltzoff, & Kuhl, 2015), as well as how language is processed by bilinguals (e.g., Marian, Spivey, & Hirsch, 2003).

Many of the newer findings in this field depend on new methods. For example, eye-tracking with special cameras, some head-mounted, has allowed researchers to see what children are attending to as they listen, speak, and interact (e.g., Casillas & Frank, 2017; Smith et al., 2015; Fausey, Jayaraman, & Smith, 2016; Yu & Smith, 2013; Chapter 7, this volume). And new techniques for analyzing data have allowed researchers to detect patterns of change that might not have been noticed otherwise (e.g., back-tracking in dense corpora: Pine & Lieven, 1993; Lieven et al., 1997; see also Chapter 4, this volume). Some researchers have focused on Bayesian analyses in order to track the frequencies of specific words and constructions during acquisition. One drawback of such analyses is that they don't deal with the effects of interaction between adult and child speakers. But interaction appears to be a vital component in the process of acquisition.

As researchers learn more about language and gesture in communication, they will find more questions about how adults and children communicate, how much they rely on gesture – hands, head, facial expressions, body stance, for example – and how much on language, as well as how these means are integrated within utterances at different ages and stages in order to communicate effectively.

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# 2

# NEURAL BASIS OF LANGUAGE ACQUISITION

*Angela D. Friederici and Jens Brauer*

Language processing is a product of the human brain. In this respect, language acquisition and language development should also be considered in the context of brain functional and brain structural changes during child development. Using electrophysiological and functional imaging methods, the brain bases of specific processes can be observed directly and compared depending on age and language development status. This direct access provides a significant opportunity to gain a deeper understanding of the processes underlying language development and to understand language as a neurocognitive function. At the same time, structural-anatomical aspects of brain development can be considered in connection with milestones in language acquisition, thus demonstrating the crucial building blocks and connections of the language network in the brain and its development. This chapter introduces important experimental methods as well as the neurocognitive foundations of language development, and explains their relevance by a number of important empirical findings. For related topics in language development, see Chapter 18 (this volume) on developmental language disorder and Chapter 17 (this volume) on individual differences in language acquisition.

## Language as a specifically human trait

Animals and even plants communicate information between members of a species and even between different species based on chemical or physical, visual, or acoustic signals. This may be the scent or luminous color of a flower that attracts bees or other insects, the magnificent plumage of a mature male bird of paradise that seeks to impress a female, or the warning call of a meerkat when a bird-of-prey approaches a member of its group engrossed in foraging. Humans, however, are the only species that has developed a language, that is, an abstract system of signs and sounds that, via phonological units, maps speech to a semantic/conceptual level and can be combined into arbitrary phrases and sentences by the rule system of syntax. Language allows us to talk about things we see or hear, as well as those we can neither see nor hear, things that happen in the here and now, and those that are yet to come. We can ask questions or share a thought. We can even discover the thoughts of bygone cultures when they have written them down and we understand how to read their script.

Despite the complexity of human language, children acquire it seemingly effortlessly. At the same time, the developmental stages that a child goes through in her or his language acquisition

are strikingly similar, independently of which mother tongue she or he learns. First vocalizations during babbling consist of combinations of vowels and consonants; first words become two-word and multi-word phrases, and later more complex sentence constructions (Kuhl, 2010). It seems that all children follow a biologically predetermined program of language acquisition. The resulting language processes are based in the brain. In order to gain a better understanding of this language organ, various experimental methods have been employed. These make it possible to study the brain functions underlying language processing and its development, to describe anatomically those brain regions responsible for language and their developmental changes, and to correlate these with increasing linguistic abilities and important milestones in language development. For a better understanding of the contents presented in this chapter, important terms of linguistics and the neurophysiological and neuroanatomical methods are defined in the glossary of this volume.

## Experimental methods for examining the neural basis of language acquisition

From the large number of available neuroscientific empirical methods, only a certain selection are considered for studies of language development. In principle, these are only non-invasive methods for studies on humans, and especially children, which have demonstrated safety for use with these populations. For all methods that fulfill this criterion, such as electroencephalography (EEG), magnetoencephalography (MEG) or magnetic resonance imaging (MRI), there are specific sets of research questions that favor or disfavor their application. For example, questions of spatial-anatomical classification are better answered by certain methods, whereas questions regarding the temporal timeline of processing are best addressed using alternative methods.

Electrophysiological methods such as EEG or MEG that measure the brain's activity in a millisecond range are very good at detecting the timing of neural processing. This can be crucial when it comes to studying the very rapid electrical charge patterns of brain nerve cell activity. In MEG, the magnetic fields associated with the electrical activity are detected, which propagate to the coils of the MEG at light speed; these magnetic coils are arranged in a hood over the head of the study participant. The magnetic field spread, distribution, and change provide information about nerve cell activity. Next, we will introduce the method of EEG in more detail, as this is a common method in studies with children. For an EEG experiment, electrodes (from as few as about four to as many as 256) are attached to the scalp of a participant. These are capable of directly registering the very small electrical impulses of nerve cells in the brain beneath the scalp. The signals are being amplified and digitized to a computer where the signal strength is recorded for each time sample. Moreover, the time sample can be matched up to the exact timing of stimuli presented to the participant, such as sounds, words, or sentences. Thus, the electrode signal can then be a portion of the EEG that coincides with the onset of each stimulus event that can be averaged over the multiple stimulus presentations. Thereby the electrical activity of other nerve cells that are unrelated to processing the stimulus is random in relation to this stimulus, and thus averages out as noise. The result is a so-called event-related potential (ERP). Figure 2.1 schematically shows the steps of an EEG derivation towards an ERP.

Another method that enables measuring the brain's function and structure is magnetic resonance imaging (MRI), either as functional MRI (fMRI) or as structural MRI (sMRI). Functional MRI measures the metabolic changes that underlie brain activation. Because these processes, such as blood oxygen saturation or glucose metabolism, are slow, fMRI can only

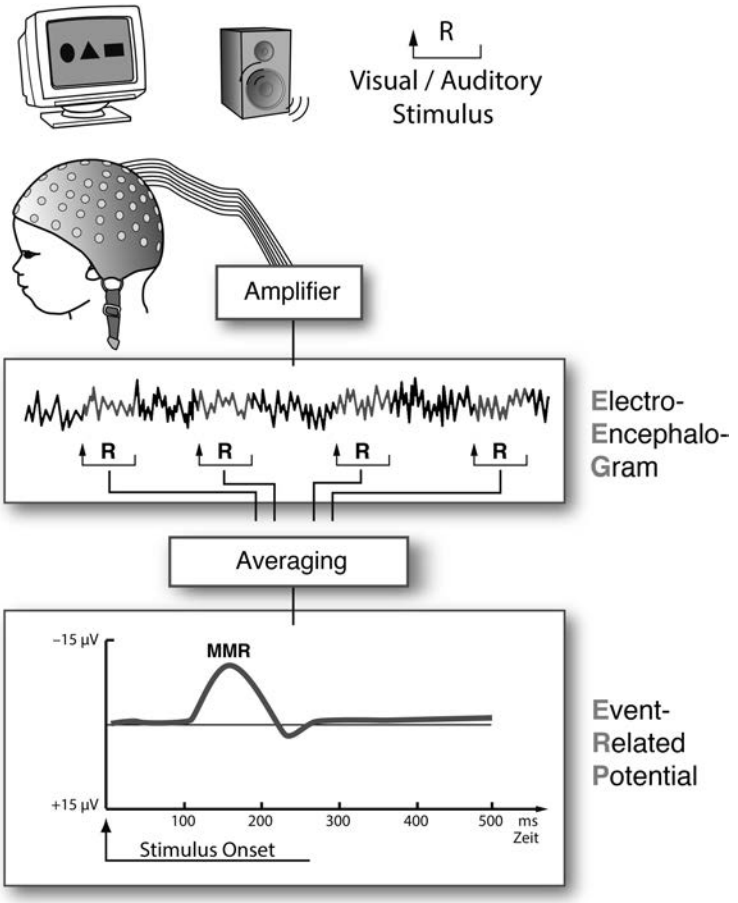



*Figure 2.1* Electroencephalography (EEG) registers the neuronal activity of nerve cells via electrodes. This signal is recorded and averaged over several similar visual or auditory stimuli, timelocked, i.e. mostly timed at the beginning of each stimulus presentation (stimulus onset). As a result, the continuous EEG signal becomes an averaged signal coupled to the event of stimulus processing. It becomes an event-correlated signal; therefore one speaks of the event-related potential (ERP). Its waveform is described by the polarity of the waveforms and the latency of the occurrence of peak waves, but also the duration and amplitude of the wave patterns. Note: As a convention, negative values are displayed upwards.

*Source*: Adapted from Friederici (2009).

describe brain functional processing in the range of seconds. However, the great strength of fMRI lies in its very high spatial resolution. Here, processing brain regions can be precisely assigned at the millimeter range. In addition, MRI is also able to create very accurate three-dimensional anatomical maps of the brain's structure, both gray matter and white matter. Brain structures involved in language processing can be examined by means of sMRI, and those structures' morphological development can be described. It is worthwhile first of all to take a closer look at these brain structures and the language network formed by them.

## The network of brain regions processing language

The human brain includes the neurons, their connections, and other cell types of the central nervous system located in the cranium. In the cerebral cortex (cortex, gray matter), the nerve cell bodies are located with their connecting nerve fibers right below (white matter). The actual information processing of the nerve cells of the brain thus takes place in only a few millimeters of the cortex. However, it is the connections between about 90 billion neurons plus other supporting cells that make up the complexity of the brain (Herculano-Houzel, 2009). Each nerve cell is connected to tens of thousands of other nerve cells via synapses, creating a network with other nerve cells (DeFelipe, 2015).

A glance at the brain reveals the ridged structure of its outer surface (Figure 2.2). The ridges (gyri) and furrows (sulci) serve to increase the surface area, so that the cortex reaches a maximum extent in a space as compact as possible. Each of these gyri and sulci have a name indicating a specific brain area. The nerve cells gathered in a gyrus or sulcus roughly correspond to a specific brain function.

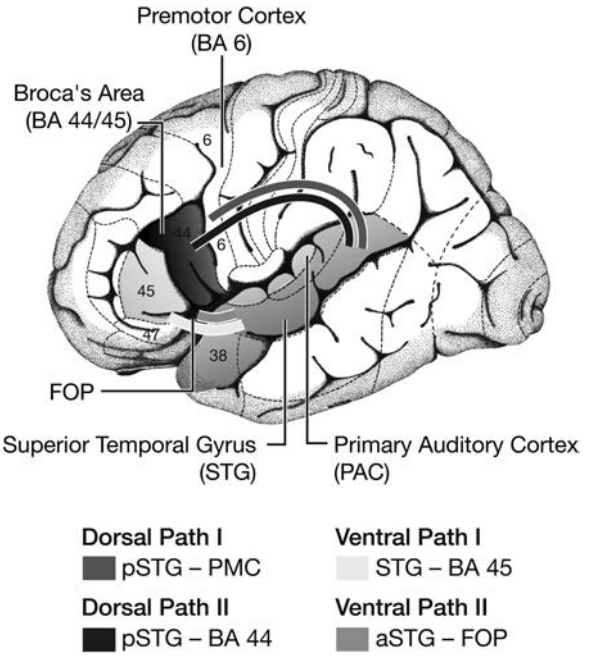



*Figure 2.2* MRI offers the opportunity to study and describe the brain structures involved in language processing. The illustration shows a view from the left on a schematic brain. The left hemisphere of the brain is functionally dominant in language processing in comparison to the right hemisphere. The involvement of the marked brain regions in language-relevant processes has been confirmed by numerous studies. In particular, Broca's area (IFG, BA 44/45) and Wernicke's area (STG) are important language-processing regions. Also schematically listed are the nerve fiber connections that make the involved brain regions an interactive network. Broca's and Wernicke's areas are connected by two pathways, one dorsal (upper) and one ventral (lower) path each consisting of two subpaths. Abbreviations: BA: Brodmann Area, IFG: inferior frontal gyrus, FOP: frontal operculum, PMC: premotor cortex, aSTG: anterior portion of the superior temporal gyrus, pSTG: posterior part of the superior temporal gyrus.

*Source*: Adapted from Friederici (2011).

It is important to understand that individual brain regions are not active in isolation, but, as mentioned above, are always involved in networks (e.g., Friederici, 2011; Hickok & Poeppel, 2007). It is this interconnectedness that makes the complexity and multimodality of brain functional processes possible, and it is the complexity of these neural networks of the brain that contribute to its computational power. The direct connections between inferior frontal gyrus (IFG) and superior temporal gyrus (STG), that is, between Broca's and Wernicke's areas of the language network, can be found along two fiber pathways. There is a ventral, lower connection, via the nerve fiber bundle of the inferior fronto-occipital fasciculus (IFOF) and a dorsal, upper connection, via the fiber bundle of the superior longitudinal fasciculus (SLF) and the arcuate fasciculus (AF). This dorsal pathway splits into two parts, one which targets the premotor cortex and develops earlier in life and one which targets the IFG and develops later in life (Perani et al., 2011). Figure 2.2 shows the most important of the language-processing brain regions and their nerve fiber connections, which together form the core of the language network.

## The seminal works of Paul Broca, Carl Wernicke, and Korbinian Brodmann

As early as the mid-19th century, the importance of the IFG for language processing was recognized by the French physician and anatomist Paul Broca. Broca treated a patient who was not able to speak freely in complete sentences, but could express statements and questions through intonation of a single syllable, the syllable "tan", for everything he said. Monsieur "tan", as he was later recognized in the literature, was examined *post mortem* (after death) by Paul Broca. He realized that this patient had a lesion in the left frontal lobe, exactly located in the IFG. On the basis of these findings and the man's clinical symptoms, Broca described the IFG as a production language center (Broca, 1863). A few years later, his German colleague Carl Wernicke, coming from his work with aphasic patients, deduced the importance of the dorsal part of the temporal lobe, especially the STG, as a sensory language center for understanding speech (Wernicke, 1874). As a result, the production and the sensory language centers described by Broca and Wernicke have been jointly entered into the literature as the first model of the language network.

Today, we know that language processing is somewhat more complex than a simple division between a sensory area in the STG and a production area in the IFG. For example, the important role of Broca's area in understanding sentences and syntactic information, that is, a language-sensory function, is much better understood nowadays (Friederici, 2017). Nevertheless, the work of Paul Broca and Carl Wernicke yielded important pioneering achievements, on which current research on the neuroanatomy of language processing is based.

At the beginning of the 20th century, the German physician and neuroanatomist Korbinian Brodmann was able to fundamentally expand previous knowledge of the neuroanatomy of the cerebral cortex (Brodmann, 1909). On the basis of meticulous cytoarchitectonic studies, Brodmann recognized that the cerebral cortex is composed of fields of different cell architecture, and he already suspected that cytoarchitectonic mapping would also have to be reflected in functional characterizations of the respective areas. It is Brodmann's areas (BAs) 44 and 45, which we today jointly refer to as Broca's area, and BA22, which is called Wernicke's area, that are so important for language processing.

## Aspects of language processing in the brain

For a better understanding of the neural foundations of language development, it makes sense first to look at how language is processed by the adult brain as a model on the basis of which

the changes in the developing language-processing system can be better understood. Language comprehension is based on the processing of phonological, syntactic, and semantic information, which taken together make up what we call language. During processing, the speech stream first reaches the primary auditory cortex (PAC) and then adjacent areas of the temporal lobe (STG), and undergoes acoustic-phonetic analysis (cf. Figure 2.2). These are processes taking place in the first 100 ms. Already shortly thereafter, until about 200 ms, the information processed in this way is integrated into a first phrase structure, facilitating the association with further incoming information from the speech stream to form meaningful units. Already at this time, an information exchange with frontal brain areas takes place. After about 400 ms, there is a semantic, that is, content-related, analysis, while at the same time syntactic information is further processed beyond the initial phrase structure formation. A fronto-temporal network involving IFG and STG is responsible for both these processes, whereby sentence-level semantic processing is mainly located in the ventral part of the IFG (BA 45/47), and syntactic information is mainly processed in the dorsal part of the IFG (BA 44) (but see also Hagoort & Indefrey, 2014). As a result, the fronto-temporal information exchange of semantic information relies to a larger extent on the ventral network connections, while the dorsal network connection is mainly responsible for syntactic information. Finally, syntactic and semantic information is integrated by 600 ms. This final process can be located in the posterior part of the STG. The steps of language processing described here are primarily located in the language network of the left hemisphere outlined above. However, the right hemisphere is not inactive. It is merely somewhat more weakly involved, while the left hemisphere is dominant. However, there is an aspect of linguistic information that is mainly processed in the right hemisphere, namely, prosody. Prosody covers the aspect of suprasegmental phonological information, that is, intonation or speech melody that emphasizes syllables, words, and sentences. Prosodic processing takes place in a right-hemispheric fronto-temporal network which corresponds to the semantic and syntactic processing in the left. A comprehensive overview of the neuroanatomy of language processing can be found in Friederici (2011).

The temporal processing steps in the mature system described here can each be assigned specific ERPs in EEG. These mature ERP components can be compared to the corresponding components that characterize language processing in the developing language-processing system in children. This allows conclusions for the description of the functional neurocognitive processes required for language acquisition. In the following, we will take a closer look at one of these ERP patterns, and provide an empirical example to shed light on the relevance of this pattern for the study of language development.

## *Early processing of phonological information*

For the entry into language processing, it is assumed that infants learn to recognize and use phonological patterns from their speech input very quickly. A prerequisite for this is the ability to capture and process corresponding phonological features. Infants are able to distinguish consonants from vowels very early, as had been demonstrated by behavioral studies (Jusczyk, 1999). When examining the underlying brain processes, it is important to note that infants and children are unable to perform a certain experimental task to the same extent that an adult participant would. Therefore, special methods have been established for children of this age that require less attention and are easy to use. One of these methods is a particular ERP method that does not require attention and records brain processing passively. This method is the so-called mismatch response (MMR). In this paradigm rare stimuli or events (deviant stimuli) are presented within a sequence of frequent stimuli or events (standard stimuli), for example, 500 standard stimuli with

100 deviant stimuli randomly mixed in. For the processing of speech information, such stimuli may be particular phonemes that differ in one specific feature from one another. Both phonemes are then included as a standard stimulus and deviant stimulus in an MMR paradigm and presented via headphones or loudspeakers, without the need for concentrated listening, because the MMR is an automatic ERP component. In adults, the MMR (called the Mismatch Negativity, or MMN) is an automatic and attention-independent ERP component. It reflects discrimination between the two stimuli, and shows up as a negative wave peak in the ERP between 100 and 300 ms (Näätänen et al., 2011). For infants, the MMR consists of both a positive and negative component. The negative component is an immature form of the MMR, and its latency is less clear-cut, with a longer-lasting waveform. The positive MMR is only found in infants and young children and occurs earlier in latency; it declines in amplitude with increasing age, as the negative MMR increases in amplitude and shifts earlier in latency instead (Trainor et al., 2003).

It has been shown that such patterns of discrimination are language-specific at a very early stage. Already at the age of a few months, infants show different responses to stress (prosodic) patterns in syllables, if these contradict the common stress pattern of the mother tongue (Friederici, Friedrich, & Christophe, 2007). In this study, 4-month-old infants were presented with unfamiliar words, each consisting of two syllables and accented on either the first syllable or the second syllable. German infants react with an MMR when they hear words with an emphasis on the second syllable, a stress pattern that is rather atypical (deviant) in German. In contrast, French infants, in whose native language this stress pattern is normative, respond with an MMR if the accent comes on the first syllable, which is rather atypical in French (see Figure 2.3). This can be explained by the very early influence of the mother tongue on language processing. In fact, this early influence can already be ascertained in newborns that are only few days old (Mampe, Friederici, Christophe, & Wermke, 2009). This is taken as a result of the fact that the hearing system of the fetus in the womb is able to process sounds, including the prosodic patterns of the mother's speech as an important and ubiquitous stimulus.

## *Processing linguistically relevant prosodic information*

Longer stretches of meaningful speech include prosodic information that delineates larger units. This prosodic information marks phrase boundaries and thereby syntactic phrase boundaries in a sentence. These prosodic phrase boundaries are acoustically realized by a pause, a lengthening of the pre-pause syllable, and a pitch change. Young infants are already able to detect an acoustically salient pause, but it takes until 3 years of age before children show an adult-like ERP response taken to reflect the syntactic role of the prosodic phrase boundary (Männel & Friederici, 2011).

## *The development of the functional network for processing syntactic and semantic information*

A large number of ERP studies have investigated semantic and syntactic processes during language development (for reviews see Männel & Friederici, 2013; Skeide & Friederici, 2016). These have reported semantic N400 effects (negative wave forms at 400 ms after stimulus onset) during the first year of life, and syntactic ELAN effects (Early Left Anterior Negativity) around the age of 2.5 years. The latter syntactic effect reflects the detection of a syntactic error within a simple active-mode sentence, e.g., *Der Löwe im Zoo brüllte. (The lion in the zoo roared.)* Incorrect: *Der Löwe im brüllte (The lion in roared)* (Oberecker & Friederici, 2006). However, it takes until the age of 7 years before children can detect such errors in more complex passive-mode sentences, e.g., *Die Pizza wurde im Restaurant gegessen. (The pizza was in the restaurant eaten.)* (Note that this

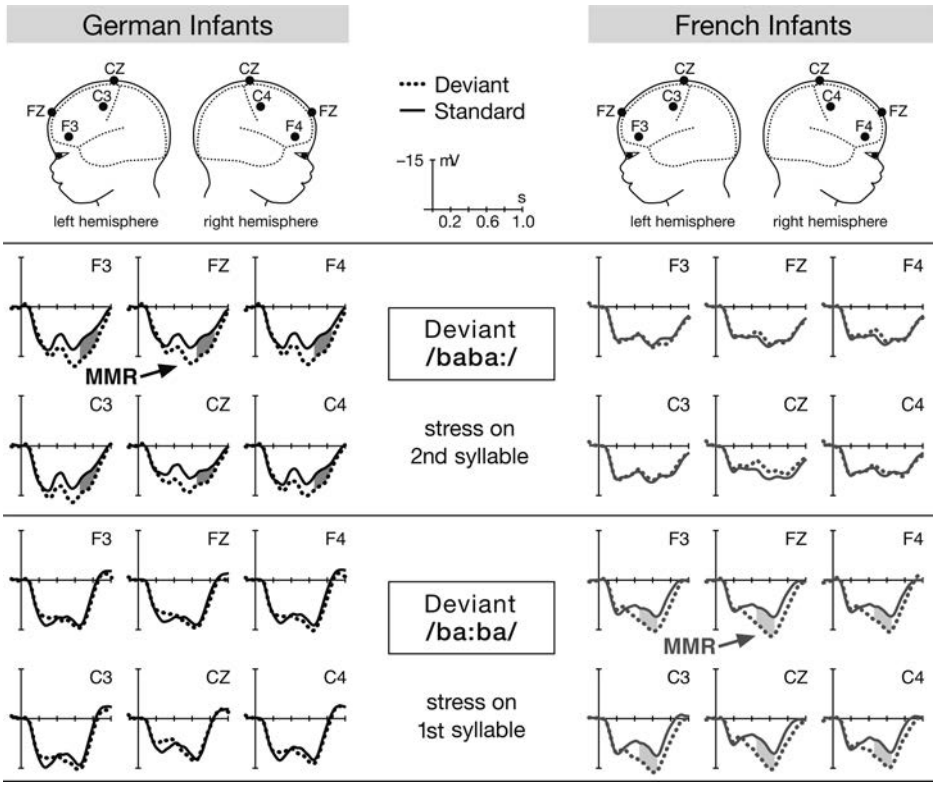



*Figure 2.3* The mismatch response of the ERP indicates a language-specific processing of the brain already in infants as young as 4 months old. Depending on their native language (left: German infants, right: French infants), the response in an MMR paradigm differs between standard stimuli (solid line) and deviant stimuli (dotted line). Note that negative is plotted upwards. German infants respond with an MMR for deviant stimuli with the accent on the second syllable (upper part of the figure), while French infants react with an MMR for deviant stimuli with the accent on the first syllable (lower part of the figure).

*Source*: Adapted from Friederici et al. (2007).

word order is correct in German.) Incorrect: *Die Pizza wurde im gegessen (The pizza was in eaten)* (Hahne, Eckstein, & Friederici, 2004). Thus, it appears that syntactic knowledge emerges first around 3 years of age, but it is not until 7 years of age that children can deal with syntactically complex sentences.

Studies on the functional neuroanatomy of language are able to pinpoint the particular brain regions involved in processing semantic and syntactic information. The most important structures of the language network have already been described above (see Figure 2.2). Basically, children use the same brain areas and neural networks as adults for language processing. However, there are some major differences that distinguish early language processing in the developing brain from that of the mature adult brain (Sakai, 2005). In the following, therefore, the focus will be on the developmental patterns of the language network regions and their involvement in processing important aspects of linguistic information. In a study on this topic, Skeide et al. (2014) show that children up to the age of 7 years do not yet process semantic and

syntactic information at the brain functional level independently of each other, as is found in adults. It is only around 10 years of age that a clear selectivity of processing syntactic information independently of semantic information becomes apparent. For this study, 3–4-year-old, 6–7-year-old, and 9–10-year-old children were invited to listen to spoken language, which included either simple, easy-to-understand sentences or i) syntactically more complex constructions or ii) semantically implausible statements. Children had the task of identifying a picture belonging to each sentence. Sentences that are syntactically complex or semantically implausible are presumed to be particularly demanding for the respective brain areas for syntactic and semantic processing, so that these regions have a higher neuronal activity that can be detected with functional MRI. In studies with adults, this has been confirmed many times (Price, 2010).

For the processing of lexical-semantic and syntactic information, children and adults use inferior frontal and superior temporal brain regions. The data show that the hemodynamic activity of the involved brain areas, especially the IFG, increases with age. At the same time, activity in the primary sensory processing regions decreases (Brown et al., 2005). The developmentally correlated increase in activity also goes hand in hand with an accentuation of the segregation of semantic and syntactic processes and the specialization of the involved cortical areas. While 3–4-year-olds mainly show an interaction effect in the STG, in 6–7-year-olds main effects for syntax and semantic processing are observed in the STG. It is only for 9–10-year-old children that this segregation yields a main effect of semantics in the STG and a main effect of syntax in the IFG, which fulfills its role in the processing of syntactic information (see Figure 2.4), as is known from studies with adults (Santi & Grodzinsky, 2007). It is also noteworthy that in adults the accentuation of functional segregation, that is, the separate location of these functions in the brain, further increases and can be observed even within the IFG (Newman, Ikuta, & Burns, 2010).

## Brain structural aspects of language development

These functional changes correlate with structural changes, and some of these changes are quite dramatic. With maturation, changes are found in both gray and white matter of the brain. In the end, it is the anatomical underpinnings of the brain's language networks that form the basis of language processing in the brain. Thus, the functional processes that change in the course of children's language development are rooted in structural changes that occur as the brain matures. Developmental changes in this respect concern the maturation of both neurons and the nerve fiber connections. The gray matter cortex thickness decreases with age because of brain development, which can be attributed, for example, to the fact that unused synapses are pruned out, while functionally active cell connections are strengthened. This physiologically meaningful and completely typical process of thinning of the cortex begins very early after birth and continues into early adulthood (Zielinski et al., 2014). Changes in the white matter nerve fiber compartment show a similar timeline of development. However, for white matter, it is rather an increase in volume (Lebel & Beaulieu, 2011). This increase is based on the volumetric growth of the nerve fibers (axons), as well as increasing myelination of the medullary sheaths, which wrap around the axons and influence conduction of action potentials (Paus, 2010). Stronger myelination leads to faster conduction and thus to more effective exchange of information between spatially separated brain areas that are organized in a network (Jones, 2004). An MRI method called diffusion imaging provides valuable insights here, as it allows an indirect but reliable examination of the fiber connections of the brain.

Of particular interest for the development of the language network are the nerve fibers of the ventral and dorsal pathways between the temporal and frontal language-processing brain areas

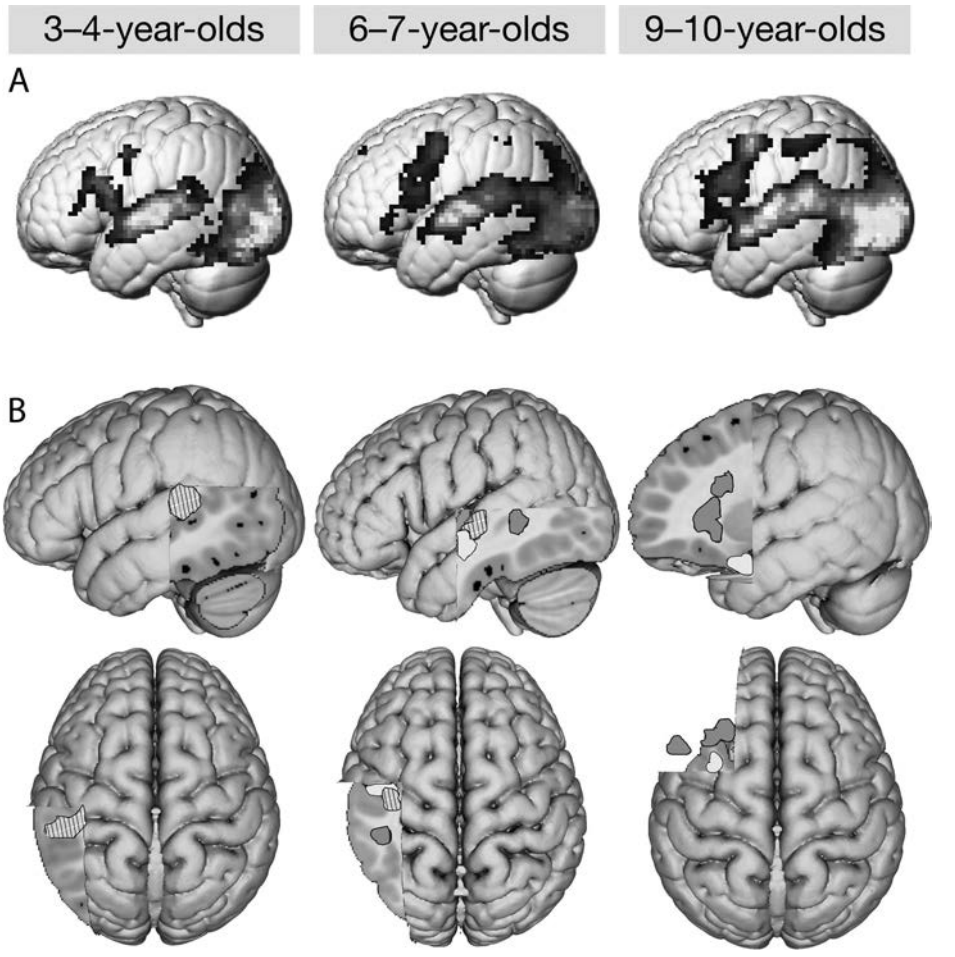



*Figure 2.4* Brain functional activation during language processing of spoken sentences for three age groups (3–4-year-olds, 6–7-year-olds, 9–10-year-olds). (A) Activation of the language network in all conditions (baseline contrast). (B) Statistical maps in a view from the left and from above for the main effects of activation for syntax (syntactic complexity, dark grey) and semantics (semantic implausibility, white), as well as the interaction of syntactic and semantic information (striped). With increasing age, a stronger segregation of the processing of syntactic and semantic information can be observed as well as an increasing involvement of the IFG.

*Source*: Adapted from Skeide et al. (2014).

that we introduced above. Structural imaging data from newborns, 7-year-olds, and adults have shown that the ventral pathway is already well formed in newborns and continues to increase in volume during childhood until it reaches full strength in young adults (Brauer, Anwander, Perani, & Friederici, 2013) (see Figure 2.5). At the same time, the dorsal pathway is maturing, in particular with respect to the two portions targeting two different termination points in the frontal cortex. The connection between the temporal lobe and the premotor cortex is already well developed in newborns. In contrast, the connection to the IFG (BA 44) is not readily observable in newborns, and visible only from the age of 7 years on (see Figure 2.5). This does

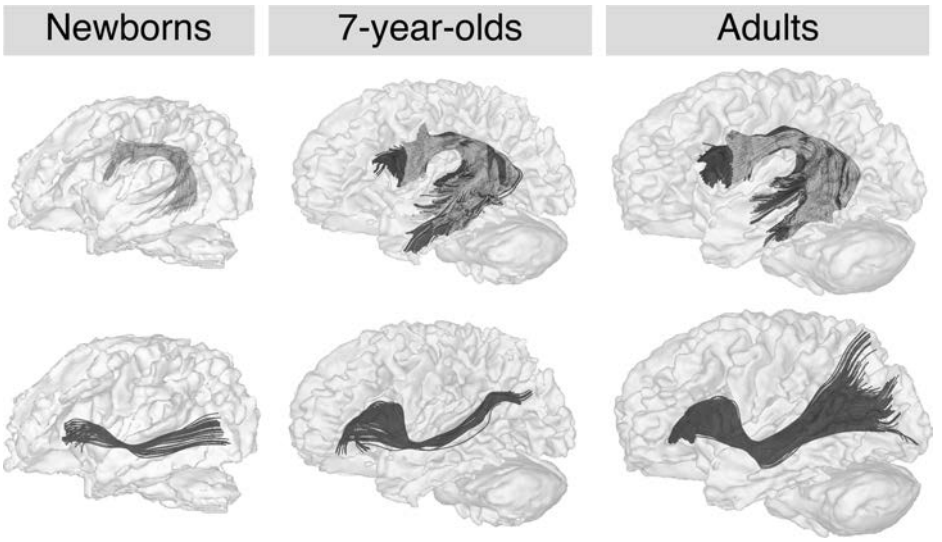



*Figure 2.5* The nerve fibers of the language network connect the frontal and temporal brain regions via the fiber connections of the dorsal and ventral pathway (cf. Figure 2.2). These two pathways are shown here in the brains of newborns, 7-year-old children, and adults. The ventral pathway along the IFOF (dark gray, lower row) is already easily recognizable in newborns and continues to evolve (cf. 7-year-olds and adults). In adults, the dorsal pathway along the AF (upper row) shows a clear differentiation of its subcomponents, which either terminate in the PMC (light gray) or reach into the IFG (dark gray). Even in 7-year-olds, these two components are easy to distinguish. In newborns, however, the connection to the IFG is not yet observable. Abbreviations: AF: arcuate fasciculus, IFG: inferior frontal gyrus, IFOF: inferior fronto-occipital fasciculus, PMC: premotor cortex.

*Source*: Adapted from Brauer et al. (2013).

not necessarily mean that the connection between the temporal lobe and Broca's area does not exist in newborns, but that it is so weak and immature that it remains invisible to the diffusion imaging method. The late maturation of this fiber tract to Broca's area has consequences for early language processing in children. It can be assumed that the fiber connection to the premotor cortex, which is already well developed in newborns, fulfills important sensorimotor functions that are necessary for the perception and production of speech sounds (Saur et al., 2008). This fits in well with the rapid development of phonological processing, both receptive and productive, which is remarkably pronounced already in infancy. But advanced language functions, such as complex syntactic processing, require the involvement of the IFG and its mature integration into the language network. As illustrated above, it takes several years for the dorsal fiber pathway to mature enough to establish a sufficient fronto-temporal network. It is interesting to note that the dorsal pathway is not fully developed even at 7 years of age; children of this age still show problems coping with syntactically complex sentences (Brauer, Anwander, & Friederici, 2011). They also do not yet selectively activate BA 44 in response to syntactically complex sentences. It has been demonstrated that the maturational status of this pathway predicts children's performance on processing syntactically complex sentences (Skeide, Brauer, & Friederici, 2016). It is therefore not surprising that the structural language network of children continues to co-develop with their language ability right up into mid-school age, especially when it comes to the processing of syntactically more complex structures.

## Conclusion

Studies on the brain functional and brain anatomical foundations of early language development are still rare. Nonetheless, their findings already provide a promising starting point for a deeper understanding of the developmental and maturational processes in the brain network responsible for language processing. Directly observable neurocognitive processing patterns in infants allow us to draw conclusions about the development of specific processing steps of linguistic information. The comparison across age groups allows us to identify the developmental trajectory of the language network. The currently available anatomical results point to important brain structural foundations that enable successful language development.

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# 3

# THE GENETICS OF LANGUAGE ACQUISITION

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## Introduction

Language acquisition in early childhood is remarkably robust. Even in cases of severe neurological disorders, a child's ability to understand and use language is often preserved to some degree. Such findings demonstrate the human drive to communicate and underpin the idea that language is innate (Pinker, 1994), and therefore is likely to be genetically driven. There has been considerable debate in linguistics, philosophy, psychology and genetics as to whether language acquisition is innate or taught, a blend of both, or perhaps a balance which shifts at different points in a child's development. This chapter will focus on the current understanding of the role of genetics in language. When thinking about the role of genetics in language acquisition, it is important to consider it within a framework of other external influences discussed elsewhere in this book.

The extent to which language ability is inherited, or heritable, is well established in the field (Barry, Yasin, & Bishop, 2007; Bishop, Adams, & Norbury, 2006; Stromswold, 1998). Genetic factors play a key role in an individual's ability to successfully acquire and use language. Many genetic factors are usually involved, and they interact both with each other and with environmental factors in a complex way. In this chapter, we will explore how genetics contribute to language, and how new genetic techniques can offer inroads into the molecular basis of language acquisition. We will also discuss the limitations of genetic studies, what they cannot tell us, and how this fits with our current understanding.

Genes do not act in isolation, and it is clear that environmental factors also play an important role in the acquisition of language. For example, maternal education level, and by proxy socioeconomic status, is associated with the academic and language abilities of their children (Reilly et al., 2010). A similar story is seen in measures of general cognition; that the mother's socioeconomic status is associated with a child's IQ (Hanscombe et al., 2012). We discuss some of the key findings of gene x environment studies and provide a snapshot of the current understanding in the field, considering some of the limitations of this type of study design.

The relationships between language and other aspects of cognition are equally difficult to disentangle. As Vygotskiĭ noted, "a word devoid of thought is a dead thing, and a thought unembodied in words remains a shadow" (2012, page 153). Language ability shows a strong association with generalized cognitive ability: a high functioning child will generally develop

more advanced language at an earlier age, and, conversely, a cognitively delayed child will be more likely to struggle to meet language milestones. Language ability is also strongly linked to other developmental domains such as reading, which closely relate to and influence each other. As such, these related domains need to be considered as part of a spectrum, and not as independent phenotypes. In terms of scientific study, this can be extremely challenging. At a physiological level, language and speech are separate faculties (a mental representation and the realization of that representation, accordingly). Nonetheless, these two attributes are intricately intertwined and can be difficult to disentangle at the behavioral level. For this reason, we have chosen to use "language" as an umbrella term encompassing both.

In this chapter we explore the current field of play in the genetics of language acquisition. We begin by discussing the heritability of language and the role of family and twin studies in the understanding of language. We go on to explore the inheritance mechanisms that are implicated in language development. Finally, we look forward by considering how modern DNA sequencing approaches are revolutionizing the field of language genetics.

## The heritability of language

There have been many studies that use twin pairs to evaluate the relative importance of genetics in language ability. These studies compare specific traits between monozygotic (or identical) twins, who share their entire DNA sequence, and dizygotic (or non-identical) twins who, on average, share half of their segregating DNA, that is, a similar level to ordinary siblings. Heritability studies look at the variation of a trait between and within twin pairs. They estimate the proportion of variation in a given trait that can be explained by genetic factors. Heritability estimates range from 0.0, for a trait that is entirely environmental, to 1.0, for a trait that is entirely genetic.

Environmental effects are often unique to any given individual (e.g. bumping your head as a child, or getting ill from a virus). This means that relationships between environmental factors and outcomes can be hard to predict unless we have a very detailed history across lots of individuals. Because twins are born and reared together, however, we can assume (rightly or wrongly) that they have a higher level of shared environmental factors (e.g. number of books in the home, number of days of education, parent's socio-economic status) than two members of the general population (or even two members of the same family). This assumption provides a powerful mechanism by which we can estimate the importance of shared environmental influences upon a trait. If a given environment is shared between twins, and if this environment directly affects an outcome, then any given twin pair should be more similar to each other than to any other member of the study population in terms of this outcome. This is true for all twin pairs, regardless of whether they are identical or non-identical. Similarly, by considering similarities between twin pairs, we can estimate the relative importance of genetic effects. Identical twins share their entire segregating DNA sequence. Thus, if genetic factors influence a given outcome, then identical twins should be similar to each other in terms of that outcome. However, this tenet does not hold true for non-identical twins who, on average, share only half of their DNA sequence.

Given that shared environment and genetic influences show different patterns of correlation between and within twin pairs, we can use these patterns of variation to estimate the relative importance of each of these factors. If a trait is purely genetic, then monozygotic twins will always have the same outcome and dizygotic twins will have the same outcome half of the time. If a trait is purely down to shared environment, then both monozygotic and dizygotic twins will always have the same outcome as their twin. If a trait is purely due to unique environment, then there will be a random pattern between twin type and outcome, and, on

average, both types of twin pairs will have the same outcome about half of the time. In reality, no trait can be clearly characterized into one of these three boxes, but by looking at patterns of variation within a trait, we can estimate the importance of genetics and environment. A major benefit to performing studies of this type is that these methods do not necessarily require us to actually look at the genetic information to estimate heritability and can be performed on large longitudinal study data sets.

An important finding in behavioral genetics is that the heritability of intelligence increases steadily throughout life. In infancy, genetic influences account for about 20% of variation in intelligence. In adulthood, they account for about 60% of variation. This, so-called Wilson effect is thought to reflect a "genetic-amplification" procedure in which children select differential environments that compound their genetic propensities across a life-span (Plomin & Deary, 2015). Interestingly, Finkel, Pedersen, Plomin, and McClearn (1998) found that language ability was strongly and stably heritable across the adult life-span, and, perhaps unexpectedly, that in this particular study language was independent of general cognition. This finding is supported by more recent studies which suggest that gene x gene and gene x environment interactions become increasingly important in verbal ability in later life (Reynolds & Finkel, 2015).

The Wilson effect is primarily reported in adult samples and in studies of general intelligence. However, the trends described are echoed in studies looking at language acquisition. In their study of children spanning 2 to 12 years old, Hayiou-Thomas, Dale, and Plomin (2012) found that environmental factors accounted for most of the differences seen in the 2 to 4 year old group, while heritability increased between the 2 to 4 and 7 to 10 year old groups. Their work suggested that genetic factors may become increasingly important as a child develops. Tosto et al. (2017) refined this even further, and showed that the heritability of language skills increases from age 7, 12 and 16. They also showed a strong genetic correlation between oral language and reading comprehension at the ages of 12 and 16, and to a lesser extent between oral language and reading fluency at 7, 12 and 16. These findings again reflect studies of cognition showing that although the influence of genetic factors increase over a life-span, it is the same set of genetic factors that influence cognition over time. Furthermore, it is found that the same set of genes influence multiple aspects of intelligence, from vocabulary to spatial memory to processing speed and executive function. These studies clearly show that genetics plays an important role in the acquisition and maintenance of language throughout life but also that these effects can be moderated by the life course.

What is more challenging to delineate is the specific role of genetic factors across generalized cognition, language and reading ability. The overlap of these developmental domains remains one of the biggest challenges in behavioral genetics.

## Heritability in language disorders

In addition to looking at heritability of language ability in the general population, there have been several studies which specifically investigate the heritability of language disorders. The term "language disorder" is the diagnosis given to children with persistent difficulties in the use or understanding of language (Bishop et al., 2017). Within this broad umbrella term for all children who struggle with language, there are several more specifically defined sub-groups. These include developmental language disorder (DLD), which overlaps heavily with the previously used category of specific language impairment (SLI), in which a primary language difficulty exists without any other explanatory factor such as autism spectrum disorder (ASD), hearing loss or developmental delay (see Chapter 18, this volume). Childhood apraxia of speech (CAS), also known as developmental verbal dyspraxia, is a specific fine motor control disorder affecting

speech production, and ultimately language ability, frequently due to mutations in the *FOXP2* gene. Individual differences and language impairments are discussed in detail in Section 3 of this volume.

Developmental language disorder is extremely common and occurs in 7% of school age children, meaning we would expect to find two children with DLD in every primary school class of thirty children (Norbury et al., 2016). The long-term effects of language disorders present a significant burden on individuals and society alike. Children who struggle with language have a greater chance of developing anxiety and depression in adolescence (Conti-Ramsden & Botting, 2008), and are more likely to have lower socio-economic status in adulthood (Ruben, 2000). Despite the clear social and economic importance of understanding DLD, we still do not understand much of the underlying etiology.

DLD has been shown by a number of studies to be highly heritable (Bishop, North, & Donlan, 1995; Hayiou-Thomas, Oliver, & Plomin, 2005; Lewis & Thompson, 1992), and it is clear that the risk of language disorder is increased if a first degree relative has a language disorder (Stromswold, 1998). Interestingly, studies have shown that language shows a higher degree of heritability in the lower range of language ability in children, than the population in general (Dale et al., 1998; Spinath, Price, Dale, & Plomin, 2004). This finding may suggest that shared genetic factors are more relevant to the extremes of the ability spectrum, compared to the typical range.

The understanding that environment is important in general cognitive ability (Finkel et al., 1998) and that interactions between genetic and environmental factors can influence the heritability of traits across time is crucial for the way in which we conceptualize both language acquisition and language disorders (Bishop & Hayiou-Thomas, 2008). Differences in testing procedures, how and when a child received a referral to speech and language clinics, and IQ can all affect the clinical diagnoses, which in turn can affect heritability estimates.

## Limitations of heritability studies

Heritability studies have provided many key insights into the genetics of both language acquisition and language disorders. There are, however, some important limitations to this methodology that should be considered. Heritability studies measure a particular trait, in a particular population, at a specific time. The way in which a trait is measured, the time at which the measurements are taken, and the study population can affect heritability estimates. As discussed below, genetic and heritability studies usually only consider additive genetic effects, rather than gene x gene and gene x environment interactions. This is an important point given that we know genetic effects themselves can change over time, responding to differing environmental pressures. As heritability studies consider one trait (or a small number of traits), they cannot capture the multitude of factors that may be relevant at any one time. Similarly, differences in inclusion criteria or how a trait is measured may have a major impact on how heritable a trait is found to be (Bishop & Hayiou-Thomas, 2008). This last point is especially pertinent to language disorders which currently lack gold-standard testing procedures.

Twin studies suggest that heritability may vary for different aspects of language; for example, heritability estimates of speech production tend to be higher than those for vocabulary (Bishop & Hayiou-Thomas, 2008; Hayiou-Thomas et al., 2006). This adds a further challenge in determining heritability, as differences exist between sub-phenotypes of global language ability and it is not always easy to distinguish between these subtypes.

There are also challenges with dealing with differences between monozygotic and dizygotic twin groupings when it comes to the consideration of language-related traits. For example,

simply being born a twin is associated with delayed language, particularly for monozygotic twins. Termed the "twinning effect" (Rice et al., 2014), this may act to decrease estimates of genetic heritability by over-estimating shared environmental influences. Rice et al. (2017) recently showed that the twinning effect detected in younger children becomes less pronounced between 4 and 6 years old as twins successfully catch up to their single child peers. Similarly, they showed that the monozygotic twin pairs caught up to their dizygotic and single child peers, and from 4 years old the twinning and zygosity effects are no longer detectable.

Heritability studies have provided some interesting insights into language acquisition and allow us to model changes in relative influences over the life-span. While they have shown unequivocally that genetic factors play an important role in language, as in all genetic studies, they rely upon the binary concepts of genetics and environment. This oversimplifies the biological complexities of the genome, and how it interacts with conditions in a molecular pathway, in a particular cell type, at a specific point in development, at the mercy of a plethora of environmental factors. Heritability studies indicate that genetics may be important, but they do not allow us to identify which specific genetic variants, molecular pathways or cell types are involved. To begin to understand the underlying neuromolecular pathways involved in language acquisition, we need to undertake molecular studies which look at specific genes.

## The study of language through extreme traits

Language ability is thought to be a continuous and normally distributed trait, with most people falling around the mean of the bell curve of ability, and fewer people at the extreme ends of the range. As mentioned above, heritability studies indicate that the same genetic effects contribute across the distribution of ability but that heritability increases at the extremes. To a geneticist, therefore, the extremes of this spectrum (that is, people who are incredibly good at language or those who struggle with language) have the potential to be the most informative. These extremes have been the traditional place to begin exploring the underlying molecular genetics of language. The underlying premise of studying participants who sit at the extremes is that the neurological pathways or mechanisms that underpin their disorder are also important to language development in the general population. These extreme traits, known in genetics as phenotypes, are the key to understanding language acquisition. Most commonly, these studies focus upon individuals with DLD. Since DLD is characterized by "unexpected" language difficulties, they are presumed to represent a "pure" form of language difficulties, reducing confounding developmental issues that may confuse an analysis.

Studying families in which several members share the same disorder has been a fruitful place to begin looking for genes and molecular pathways that may be involved in language. This approach assumes that family members with the same phenotype share the same underlying genetic cause, which results in their disorder. By investigating the regions shared between affected family members, we can identify the potential cause of their disorder.

## Mendelian genetics

Genetic studies typically focus upon large families in which a severe form of disorder is inherited in a characteristic way. These types of family-based disorders are termed "Mendelian disorders" because they show similar inheritance patterns (recessive and dominant) to those described by Gregor Mendel in his famous pea crossing experiment in the 1800s. Mendel showed that when he crossed purple flowering pea plants with white flowering pea plants, it resulted in all purple flowering offspring. When he crossed these purple offspring to create the next generation, he

always ended up with the ratio of one white to three purple flowering pea plants, indicating that the genetic factor determining white flowers was present in the first generation even though it was not visible. Mendel explained this observation by proposing that genetic factors are inherited in pairs (one from each parent). Within any given pair, some outcomes can be genetically "dominant" (such as the purple flower) and some genetically "recessive" (such as the white flower). Thus, he discovered it is possible for a pea plant to carry a genetic variant (allele) that determines purple flowers and an allele that determines white flowers. In this case, the flowers will appear purple, and the white allele will be masked but still present. While we now understand that the picture is much more complicated than this, the basic principle of the dominant and recessive models still apply to many genetic disorders and traits. Mendelian forms of language disorders are collectively rare, and may represent the most severe forms. They have, however, been extremely important in our understanding of language genetics.

To understand how Mendelian disorders can be used to understand language, we must first cover some basic genetics principles.

The human genome carries the instructions for how to build a human. It can be thought of as a book, with two identical copies carried in each cell in the body (see Figure 3.1). Each book is broken up into chapters which represent the chromosomes – individual chunks of genome packaged into discrete units. We each have 22 chapters and 2 sex chromosomes (either XX or XY), making a total of 46 chromosomes. Each chapter can be further divided into thousands of paragraphs, each representing a gene. Each paragraph contains a discrete set of instructions to build a single protein, in the form of combinations of letters arranged into words that are read by the molecular machinery within the cell. When there is a spelling mistake, or mutation, in one of these genes, it can lead to a word becoming unreadable and the meaning being completely changed. In some cases, these mutations can render the entire paragraph nonsensical as the true meaning of the sentence can no longer be interpreted by the cellular machinery. The protein

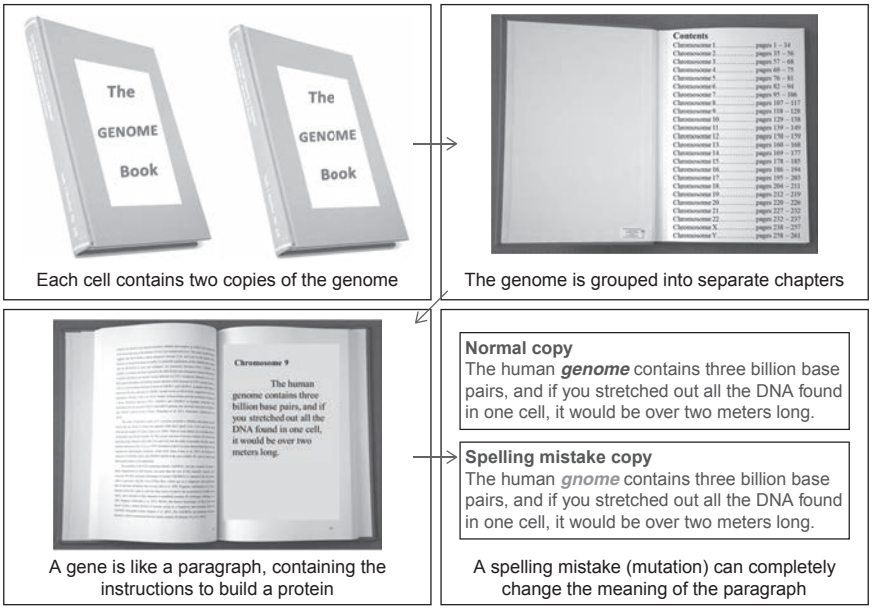



*Figure 3.1* The human genome represented as a book.

may not be produced at all or may be unable to carry out its function properly. These deficiencies may result in the person having a genetic disorder.

Examples of the patterns typical of dominant and recessive inherited disorders are shown in Figure 3.2. Figure 3.2A shows a dominant inheritance pattern in a theoretical family of six. An affected family member is indicated by a shaded shape, and males are represented by a square and females by a circle. Figure 3.2A shows an affected father (black square) and unaffected mother (white circle), and half of the children (n = 2/4) are also affected. This ratio of affected offspring indicates that the underlying cause is likely to be dominantly inherited; that is, one copy of the mutation is enough for the trait to be visible. In this instance the mutation is shared by the father and children 1 and 4. Dominant disorders are a special case where one functional copy of the protein is not enough to do the job properly, and the cell cannot function. In practice, a person still has two copies of the gene, but the dominant mutation masks the second wild-type (typical form) copy. The wild-type copy is still present, and can be passed onto offspring, but its function is overwritten by the mutant copy when both are present together. An example of a dominantly inherited genetic disorder is Huntington's disease, where affected family members develop severe progressive neurological deterioration.

In contrast, recessive disorders require both copies of the gene to be disrupted before a trait is visible. Figure 3.2B shows a recessive pedigree where both father and mother are unaffected. One of their children is affected while the other three remain unaffected. This pattern is typical of a recessive disorder. Both father and mother carry the mutation (termed "carriers"), but one

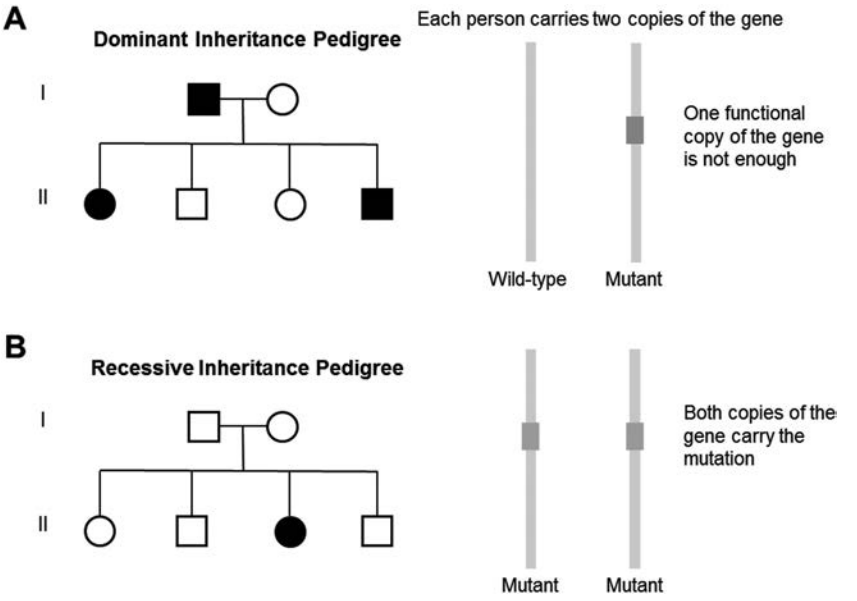



*Figure 3.2A* This shows an example dominant pedigree. Males are indicated by a square, females by a circle, affected family members are indicated by a black shape, and white indicates unaffected. In the example, the father is affected by the disorder, but the mother is not. Two of four children have inherited the mutation from the father and have the disease, and two are unaffected. Because the protein containing the mutation is dosage sensitive, inheriting only one working copy is not sufficient to produce enough functional protein.

*Figure 3.2B* This shows an example recessive pedigree. In the example, neither father nor mother is affected, but both are carriers. One child is affected and carries two mutant copies, two children are carriers (one copy), and one child is unaffected with no mutations inherited.

mutant copy is not enough to cause the disorder. By chance, one in four children will inherit two copies of the mutation (one from each parent) and so will be affected. The other three children will all be unaffected, but, on average, two of them will be carriers (one copy of the mutation inherited) and so could pass a mutant allele on to their children. If their partner also happens to be a carrier, then their children may also be affected. In recessive disorders, an affected person needs to inherit a mutation from both parents in the same gene. This combination renders the protein completely dysfunctional, leading to disease. In contrast to a dominant disorder, these proteins are not dosage sensitive; as long as you can produce some protein, the function of the cell will not be disrupted, so one copy of a mutation is tolerated. Some examples of recessive genetic disorders include cystic fibrosis, Tay-Sachs disease, and sickle cell anemia.

These example pedigrees show the odds of inheriting a Mendelian mutation under both recessive and dominant models. However, in practice, patterns can vary from this theoretical model. A point of interest is that inheriting mutations is not always deleterious. We can inherit single copies of recessive mutations without adverse effects, and some changes do not affect protein function at all. Most mutations are inherited, but, on average, 100 mutations occur new (termed *de novo*) in every generation. Some of these will be deleterious, some may be advantageous, and many will be neutral. To return to the genome book analogy, non-damaging changes may alter how a word is spelled in a sentence, but the meaning can still be clearly interpreted. These types of tolerated changes are termed "genetic variants", and are relatively common in the human genome. In general, a mutation eliminates the meaning of a critical word but may also alter the meaning to be more efficient. This is analogous to text-speak, where the spelling of words is altered but the meaning retained in a more efficient manner. These changes to the genome represent evolutionary changes that spread through families and populations over time. On average, the human genome carries around 2,000 protein altering changes (The 1000 Genomes Project Consortium, 2015), and over 1,000,000 genetic variants. The challenge in any genetic study is to figure out which of these are relevant to the disorder of interest.

Families provide a unique opportunity to study genetic contributions to disorders and traits. Children inherit half of their DNA from each parent. This means they share half of their segregating DNA with their mother, half with their father and, on average, half with their sibling(s). We can use these shared regions to narrow down our search for relevant mutations. For example, if both children in a given family are affected, we can look for regions of the genome that are shared between them, reducing our search space by 50%. Additional siblings and relatives allow us to further narrow our focus. Large families therefore represent a particularly useful tool for gene identification, particularly if they have multiple affected and unaffected family members. This approach is relatively straightforward if one mutation is involved and individuals can be classified as affected or unaffected. For example, in Figure 3.2A, we know that the father, child 1 and child 4 all share the same mutation, whereas the mother, child 2 and child 3 do not. This principle forms the basis of Mendelian genetics studies, and has been extremely powerful in understanding the underlying cause of severe language disorders in families. We will explore some of these below.

## Insights from Mendelian studies

The first, and most well-known, example of a gene to be associated with a language disorder involved the KE family (Lai et al., 2001). Several members in this large multigenerational family present with a form of language disorder known as childhood apraxia of speech (CAS) (see Figure 3.3). This disorder, described in detail in Chapter 19 (this volume), manifests with a specific difficulty in the fine motor control movements required to produce speech sounds. In their studies of the KE

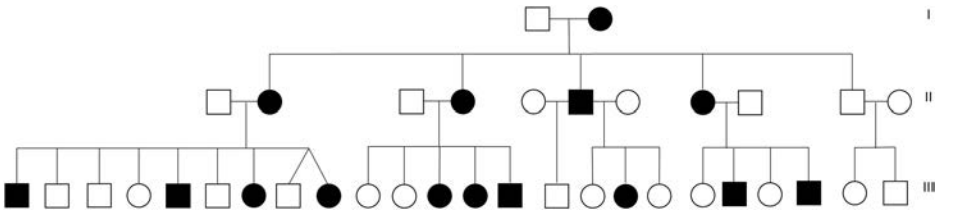



*Figure 3.3* The family pedigree from the KE family. Affected family members are colored in black, and unaffected family members are in white. Males are represented by squares, and females by circles.

*Source*: Adapted from Watkins et al. (2002).

family, Lai et al. identified a dominant mutation in the gene *FOXP2*. This mutation was found to be present in a single copy in all affected family members, but never in unaffected individuals. This gene encodes an important protein involved in the regulation of many developmental genes (Carlsson & Mahlapuu, 2002). Subsequent studies identified additional mutations in other unrelated individuals with CAS, and mutations in *FOXP2* are now a well-characterized cause of CAS (MacDermot et al., 2005; Moralli et al., 2015; Reuter et al., 2017; Tomblin et al., 2009; Turner et al., 2013). Because it regulates other genes, changes in the levels of the FOXP2 protein can have big knock-on effects upon many pathways. They are therefore usually dominant – one mutation is enough to cause the disorder. However, mutations in *FOXP2* are still extremely rare, and represent the genetic cause for only about 2% of CAS cases (Worthey et al., 2013). The KE family is an extremely unusual and special case. Cases of *FOXP2* mutations are collectively rare, and to find a large multigenerational family with a clearly dominant form of language disorder is exceptional.

FOXP2's most important and best characterized function is its role in the growth and control of neurons in the developing brain (Chabout et al., 2016; Spiteri et al., 2007; Vernes et al., 2011). This role has been shown to be important in neuroplasticity and is thought to be key to how we learn language. Studies in song-birds and mice show that FOXP2 also regulates neuroplasticity and vocalizations in other species. Perhaps somewhat surprisingly, FOXP2 is not just a brain protein, but plays a role in the regulation of hundreds of genes in many parts of the human body that are unaffected by the mutation that causes CAS. For some reason, these mutations seem to particularly affect the brain.

*FOXP2* paved the way for our current understanding of the molecular pathways involved in language development. Because of this, *FOXP2* is often referred to as a "molecular window" into speech and language (Fisher & Scharff, 2009). It has formed the basis for an entirely new field of research, and has led to a wealth of discoveries that aid our understanding. One such example is the identification of the *CNTNAP2* gene (Vernes et al., 2008), a synaptic protein which is regulated by FOXP2 and has also been associated with language disorders (Devanna et al., 2017), ASD (Alarcon et al., 2008; Arking et al., 2008) and a wide range of neuropsychiatric disorders and functions. Such studies indicate that *FOXP2*-regulated pathways are likely to be important in brain development and relevant to many cognitive processes beyond language acquisition.

The identification and characterization of *FOXP2* has facilitated important insights into how the human brain develops language. However, our current understanding is far from comprehensive, and many questions remain. Each identified pathway can open up additional questions and

networks that need exploring. For example, we know that immature neurons require guiding to find their way to the final location where they then fully mature. These represent important steps in brain development (Vernes et al., 2011; Vernes et al., 2007). Retinoic acid, a metabolite of vitamin A, has been shown to play a vital role in cellular differentiation of neurons (Devanna, Middelbeek, & Vernes, 2014) and is driven by *FOXP2*. These neurodevelopmental pathways are critical for brain function, and it appears that their role in language may be extremely important and understudied.

Aside from *FOXP2*, genetic studies have also identified some unlikely pathways in the quest to understand language disorders. One particular example is the gene *GNPTAB*, which was identified across large, multigenerational Pakistani families with persistent stuttering (Kang et al., 2010). The *GNPTAB* gene encodes a lysosomal protein that is important for the recycling of proteins within cells. This represents a basic cellular process that is relevant to all cells and, as with *FOXP2*, appears to affect brain cells in particular. Disruption of lysosomal pathways can lead to a variety of symptoms from developmental delay to seizures, deafness and blindness. Exactly how this mechanism is linked to stuttering is yet to be uncovered, but it is clear that there is still a lot to be investigated and discovered.

Insights into mechanisms can also come from the opposite end of the language ability spectrum. A recent study identified a rare variant in a Serbian family with the ability to reverse words with incredible speed and precision (Prekovic et al., 2016). The variant lies in the gene *RIC3*, which is involved in establishing communication systems between neural cells. Prekovic and colleagues showed that the family members able to speak backwards rapidly have exceptional working memory, allowing words to be reversed. The mechanisms involved in this pseudo-language may shed light on natural language-acquisition processes. This study shows that novel genes and pathways can be identified not just from language disorders, but that families with super language abilities can be just as useful in discovering new mechanisms underlying language acquisition.

## Limitations to Mendelian studies

Each of the above cases provides an example of when a family or a small number of individuals led to the identification of a gene. Each gene is part of a specific molecular pathway which leads to an improved understanding of individual influences upon language. Each new gene identified may only directly affect a small number of individuals, but it can, as in the case of *FOXP2*, open up a "molecular window" facilitating major insights in neurodevelopment and revolutionizing the field (Fisher & Scharff, 2009). Each finding is a small part of a highly complex picture, with each new insight providing a gateway into specific processes and pathways of importance. Language acquisition is clearly an extremely complex process involving many aspects of neurodevelopment and a plethora of genetic and environmental factors. It is likely that large numbers of molecular pathways play a role in the successful acquisition of language, and to gain a clear picture of how this works will be extremely challenging. Nonetheless, the more steps we can uncover, the more links we can make and the clearer the picture will become.

In each of the three cited examples, the variant responsible has fallen within the coding region of the genome, creating a clearly and easily interpretable mutation. However, the majority of the human genome does not directly code for proteins. Variations in these regions are far less well understood, but are likely to play a role in how genes are controlled. Interpreting these non-coding variants can be challenging, and as a result, clear links between genetic changes and protein function can be few and far between. As the current understanding of these non-coding variants increases, this will improve.

## Complex genetic models

Mendelian disorders represent a special case in which a single mutation is necessary and sufficient to cause a disorder that is easily identifiable and distinct from typical development. However, we know that in the majority of cases, these principles are unlikely to hold. The diagnosis of DLD is not always clear-cut. Individuals can have borderline diagnoses, simply because the inclusion criteria are arbitrarily assigned, and will often miss children who sit on this border. Even in cases where children are clearly affected, the nature of the disorder will vary between individuals and over time. DLD diagnoses represent a spectrum of severity and dimensions, and it is unclear whether the same factors contribute across these dimensions. In the majority of cases, Mendelian dominant and recessive models will not be appropriate. We have come to understand that there is not one clear genetic cause for the majority of DLD cases, but that the model instead involves many variants that interact to contribute to genetic susceptibility or risk. This is termed a "complex genetic model", meaning that each variant contributes to an individual's overall level of risk of developing a language disorder. Coming back to our analogy, this is akin to many spelling errors spread across a paragraph that obscure the meaning. While "text-speak" can make communication more efficient, the combination of contracted variations can sometimes make it difficult to understand. The knowledge of the surrounding context and external factors (such as exposure to technology) may affect the ability of the individual to cope with these combined variations. Similarly, combinations of genetic variations can put an individual at an increased risk of the disorder. A familiar example of a complex disorder is type 2 diabetes – it is a common disorder in which genetic susceptibility and lifestyle factors combine to modulate individual risk (Fuchsberger et al., 2016). Each individual genetic variant and lifestyle factor explains a proportion of the risk matrix, but the combinations of factors can differ between individuals and no one factor alone explains the majority of risk.

One successful method for identifying genetic risk variants is to perform a genome wide association study (GWAs). These look for shared variants that are over-represented in a large cohort of unrelated patients. GWAs are excellent at identifying common variants in common disease but rely upon careful diagnosis of affection status and explain only part of the genetic risk model. By definition, complex genetic disorders involve hundreds of genetic variants, many of which will only have a small impact upon risk. These variants are much more challenging to identify than the high impact variants associated with Mendelian disorder.

DLD presents several difficult challenges to gene identification approaches. Although some candidate genes (*CNTNAP2*, *CMIP*, *ATP2C2*) and chromosome regions (chromosome 15q deletions) have been identified, large-scale studies are still few and far between. Several GWAs have been completed, but no variants have been found to confer an increased risk of language disorders across investigations (Carrion-Castillo et al., 2016; Eicher et al., 2013; Gialluisi et al., 2014; Harlaar et al., 2014; Luciano et al., 2013; Nudel et al., 2014; St Pourcain et al., 2014). For a recent review of candidate genes and GWAs, we refer the reader to Carrion-Castillo et al. (2016). The lack of replication is characteristic of complex genetic disorders and is likely to reflect the low effect size of the contributory variants. In order to detect these variants, a GWAs on a huge scale would need to be performed. The goal post for the number of participants required to detect moderate impact variants is demonstrated by a recent study into the genetics of schizophrenia which tested 37,000 schizophrenia patients and an enormous 113,000 controls, which was able to identify over 100 new regions of the genome (Ripke et al., 2014). This number shows that while previous studies have provided some useful insights, they are woefully underpowered to detect moderate impact variants. Most GWAs to date have had hundreds to thousands of participants, but as evidenced by the success of the schizophrenia study, larger

numbers provide the power to detect regions with a lower effect size. GenLang (http://genlang.org/) is a global initiative set up to address the challenges of study size and standardization of phenotyping.

To conduct a "successful" GWAs, all participants must be characterized in the same way, and all cases must share an underlying genetic etiology. This can be particularly problematic for a disorder like DLD, in which we understand little of the contributing biology. When studying Mendelian inherited disorders that run in families, it is relatively easy to precisely split phenotypes into subsets, drawing clear boundaries around what constitutes DLD, and what constitutes an overlapping phenotype such as dyslexia or ASD. In unrelated individuals and for a trait that differs between individuals and over time, this can be a daunting task. If two individuals are both classified as affected but, in fact, have different conditions, the assumptions underlying GWAs will be violated and the power to detect underlying factors will be reduced.

A ray of light in this sobering reality is offered by the heritability studies described at the beginning of this chapter. Recall that these studies suggest that the genetic contributions to verbal ability are relatively stable over time and overlap with those influencing other cognitive domains. If this is true, some genetic contributions will be shared between individuals even when clinical presentations differ slightly. Thus, the GWAs approach can be used to detect these related and overlapping factors by lumping cases into broad phenotypes with shared related pathways. This premise is supported at the molecular level, where we find that some genes contribute to multiple neurodevelopmental traits (e.g. *CNTNAP2* in Rodenas-Cuadrado, Ho, and Vernes, 2014) while others may contribute to particular subsets of individuals and disorders (e.g. *DCDC2* in Scerri et al., 2011). These overlaps confound the identification of disorder-specific variants but may actually assist in the identification of variants that affect general cognition and language. It may not be possible to separate out those that impact language only from those that affect cognitive processes in general. These scenarios make performing a large-scale GWAs of DLD an intimidating and exciting prospect.

## Interactive effects and epigenetics

The complexity of language acquisition is evident from the neurological mechanisms of brain development. The genes encoded in our DNA play a vital role which we are only just beginning to understand, but they only tell part of the story. It is evident that environment plays perhaps an equally important role in language development. But how do our genes interact with our environment to make us better or worse at language? A relatively novel area of science attempts to address questions such as this by considering gene x gene, gene x environment interactions and epigenetic effects.

As explained above, we know that some genes play a general role in development while others have a more specific effect. Similarly, the role of a given genetic variant may be modulated by other variants or in particular environments. Genetic studies tend to consider specific genes or variants as independent factors, but we know that genes act within dynamic interacting pathways that are responsive to environmental factors. The serotonin transporter gene *SLC6A4* has been associated with depression. A common variation within this gene results in two alternative protein forms – a short form (s) or a long form (l). The short form has been shown to increase the risk of negative developmental outcomes, but this effect only becomes apparent when environmental stress is encountered (van Ijzendoorn, Belsky, & Bakermans-Kranenburg, 2012). Conversely, the short form is associated with positive developmental outcomes when the environment is positive (van Ijzendoorn et al., 2012). This fascinating study highlights how the same genetic variant can be associated with differential outcomes in response to a particular

environment. If the environment was not considered within a study, then the outcomes associated with the short form would be mixed and no clear pattern would be seen. It is only by this consideration that the patterns become clear. Although environment is clearly important in language and neurodevelopment, the number of dimensions associated with gene x gene or gene x environment screens currently prohibit the analysis of realistic models unless these studies are hypothesis driven.

To date, there have not been any studies published investigating the molecular gene x environment specific to language. However, it represents an exciting future direction for the field. As noted above, it is sometimes difficult to delineate genetic effects from environmental effects, particularly when considering parents and children, who often share both genetics and environment. "Gene x environment correlation" is the term given to traits which influence each other and then become part of the shared environment. This is particularly relevant to behavioral genetics, where a genetic predisposition may alter the home environment, which then affects the phenotypic outcomes. For example, a recent study found that latent factors of maternal language significantly predict storybook exposure in children (Puglisi et al., 2017). It is important to bear in mind that correlation does not equate to causality, and directionality cannot be assumed. Studies of gene x gene (Asbury, Wachs, & Plomin, 2005) and gene x environment correlation (Dale et al., 2015) have been attempted using twins, and while they are not the optimum way to tackle this question, they do represent the first studies of this exciting new approach.

The role of environmental factors in genetic susceptibility to DLD offers an interesting research route. It may be that genetic susceptibility interacts with environmental factors, such as lower socio-economic status, that put a child at a higher risk of developing a language disorder given the "perfect storm" of conditions (Virgin & Todd, 2011). That is to say, each susceptibility variant may only contribute a small amount of risk, but when inherited together, under certain conditions, they may be enough to result in a language disorder.

Another new field of research that considers differential effects is epigenetics. It refers to alterations in gene regulation in response to environmental stimuli, without changing the underlying DNA sequence. Some of these epigenetic modifications are heritable (inherited by the next generation), and some are not. Two of the most commonly referred to epigenetic mechanisms are DNA methylation and histone modification, but in general any extrinsic mechanism by which a gene is modulated can be referred to as epigenetics. DNA methylation and histone modifications refer to two different ways in which chemical modifications can modulate gene expression, and both have been related to neurological dysfunction. For example, changes in DNA methylation profile have been associated with neurological disorders, particularly neurodegenerative disorders such as late onset Alzheimer's disease (Nicolia et al., 2017). Increased histone modifications in dopaminergic neurons are associated with Parkinson's disease (Park et al., 2016). These modifications have long been recognized as methods of gene expression regulation, but recent research indicates that epigenetic changes are much more dynamic than previously thought, and can alter in response to external factors such as diet, presence of toxins, or the environment in the womb, setting up new axes of epigenetic x environment interactions. In addition, we now understand that such modifications may be inherited, leading to trans-generational changes in gene expression in response to environmental factors. Epigenetic changes therefore represent an intriguing mechanism which may partially explain the complex interplay between genetics and environmental factors, and why certain conditions result in a specific change in some people.

Epigenetic factors have been proposed as a possible contributory mechanism for DLD by several groups (Kraft & DeThorne, 2014; Rice, 2012; Smith, 2011). Although no direct associations between language disorders and epigenetic control have been reported in the literature,

recent studies do suggest a role for these mechanisms in ASD. Increased methylation of the oxytocin receptor gene (*OXTR*) and the reelin gene (*RELN*) have both been reported in individuals affected by ASD (reviewed by Loke, Hannan, and Craig (2015)). This system therefore represents a highly plausible mechanism which may be of relevance to language disorder.

## Future directions for the genetics of language acquisition

Language disorders are very common but have proved difficult to study due to the complexity of the trait and contributory mechanisms and influences. The underlying genetic mechanisms remain far from understood. Many valuable insights have come from studying families at the phenotypic extremes, and from studies looking at the population as a whole. There is still much to understand about how genetics plays a role in language acquisition.

The advent of Next Generation Sequencing (NGS) has opened up exciting possibilities for studying the role of genetics in language disorders. NGS allows for the rapid sequencing of the entire genome simultaneously, providing more complete genetic information than previously possible. The current challenge is the computational analysis that is required to make sense of such enormous volumes of data, which remains a bottleneck for genomic investigations. Similarly, NGS can be cost prohibitive, both in terms of the performing of the sequencing itself and in terms of the computational resources and expertise required to use it. NGS has revolutionized genetics, and will certainly be key to future advances in the genetics of language. Such studies (Chen et al., 2017; Devanna et al., 2017; Eising et al., 2018) are starting to appear in the literature and have facilitated the identification of new genes and pathways, although sample sizes remain small.

In the future, genetic screening could be used to identify children at an increased risk of developing DLD and help them to access the most appropriate treatment early. Intervention may well be effective, even if a child's particular disorder is largely genetic in origin, and access to the most appropriate educational support may improve the child's outcome. It may even be possible to use a genetic risk profile to guide the most effective form of educational support, using this to ensure that a child receives the most appropriate type of intervention.

Several challenges are currently being addressed by researchers around the world. The most fundamentally important are the efforts to develop better diagnostic terminology for DLD (Bishop et al., 2016; Bishop et al., 2017). These will form a solid foundation for future studies. Larger studies, with systematic phenotyping of thousands of DLD cases and controls, will allow for the identification of large and moderate impact genetic variants as risk factors for DLD. These will implicate new genes and molecular mechanisms in language acquisition, developing our understanding of how the brain learns to use language to communicate.

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# 4

# STATISTICAL LEARNING APPROACHES TO STUDYING LANGUAGE DEVELOPMENT

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## Introduction

Anyone who has spent time around young children will notice that they acquire language at an alarming rate – they go from being non-verbal in early infancy to speaking in full and grammatically complex sentences between their second and third birthdays. A question that has been of particular interest to researchers is, how do children learn language so quickly? One prominent hypothesis is that infants may begin to learn language by picking up on the patterns or structures in their linguistic environment even before they know very much about the specific characteristics of their native language – a capability that is often referred to as statistical learning.

The idea that infants can track regularities in their linguistic input was popularized in 1996 by Jenny Saffran, Richard Aslin, and Elissa Newport. They showed that following 2 minutes of familiarization with an artificial language (e.g., *pabikugolapitimore . . .*), 8-month-old infants could discriminate syllable sequences that had occurred together consistently (i.e., words) from those that spanned word boundaries (i.e., part-words). These findings suggested that infants may be able to track the co-occurrence patterns (also referred to as sequential statistics, conditional statistics, and transitional probability) between syllables to discover words in continuous speech (Saffran, Aslin, & Newport, 1996). This work has been replicated many times with other artificial (e.g., Aslin, Saffran, & Newport, 1998; Thiessen & Saffran, 2003) and natural languages (e.g., Karaman & Hay, 2018; Pelucchi, Hay, & Saffran, 2009a, b) (see Section 2 of this volume for more information about statistical learning and speech segmentation; see the Conclusions section of this chapter for extensions of this work beyond speech and humans), and such tracking is believed to occur implicitly or incidentally (i.e., without conscious awareness; e.g., Saffran, Newport, Aslin, Tunick, & Barrueco, 1997). Finding words in continuous speech is just one of the many learning challenges infants face when acquiring language. Infants also need to discover which sounds are relevant in their native language, how sound sequences map to meaning, and how elements in language are organized relative to one another, to name a few. The past two decades of research have suggested that infants have remarkable computational abilities that may allow them to track the types of statistical regularities relevant to each of these learning challenges.

Through the use of highly controlled experiments, laboratory demonstrations of statistical learning have been very informative regarding infants' capabilities. Yet we still do not know if,

and to what degree, infants rely on these computational abilities to learn language outside of the laboratory. We suggest that the field may be able to glean insight into the role of statistical learning by looking at how individual differences in statistical learning abilities relate to language development.

This chapter is organized into four sections. In each section we will begin by highlighting a language learning challenge faced by infants: 1. discovering the sounds in language, 2. finding words in continuous speech, 3. mapping words to meaning, and 4. learning rudimentary grammar. In each section we will provide an overview of the kind of statistical regularities available in the input and review a representative sampling of the evidence that suggests that infants can track those statistics (for a recent review, see also Saffran & Kirkham, 2018). For each of these learning challenges, if relevant data are available, we will discuss what is known about how individual differences in statistical learning are related to language development in both typical and atypical infant and child populations. Our goal in this chapter is to give the reader a flavor of the ways that statistical learning in infancy (and childhood) is studied in the lab and to highlight evidence to suggest that it may account for some meaningful individual differences in language acquisition.

## Discovering the sounds in language

One of the major learning challenges faced by infants early in development is discovering which speech sounds and speech sound variations are relevant in their native language. Infants demonstrate early sensitivity to many of the sounds found across the world's languages (Kuhl, Tsao, Liu, Zhang, & Boer, 2001). As they gain experience with their native language, infants tend to show reduced sensitivity to many non-native phonemes (Lalonde & Werker, 1995; Werker & Tees, 1984) and show an increased ability to be able to discriminate native-language phonemes (Kuhl, Stevens, Hayashi, Deguchi, Kiritani, & Iverson, 2006; Narayan, Werker, & Beddor, 2010). This process has been referred to as perceptual narrowing (for a review, see Maurer & Werker, 2014) or native-language attunement (see Chapter 9, this volume for a more in-depth discussion of the development of speech perception). Evidence of perceptual narrowing in monolinguals is typically observed around 10 to 12 months of age for consonants (e.g., Kuhl et al., 2001; Werker & Tees, 1984), and somewhat earlier for vowels (e.g., Polka & Werker, 1994). For infants being exposed to more than one language, there is the added challenge of learning two phonological systems, and bilinguals tend to show somewhat protracted perceptual narrowing (see Chapter 16, this volume for further information about bilingual language acquisition).

The speed with which infants learn to attend to some sound contrasts and ignore others has been of interest to researchers for a long time. One of the most prominent hypotheses is that infants home in on the sound patterns of their native language(s) by tracking statistical regularities in the frequencies and distributions of sounds in acoustic space (Maye, Werker, & Gerken, 2002; Werker, Yeung, & Yoshida, 2012). In the extant literature, this type of pattern detection is referred to as distributional learning, and is arguably one of lowest level forms of statistical learning (see Ambridge, Kidd, Rowland, & Theakston, 2015). Consistent with this idea, each of the world's languages offers the developing infant different distributions of acoustic information. So, for example, American English /r/ and /l/, which are lexically contrastive in that they can be used to differentiate word meaning (e.g., *rate* vs. *late*), are produced with a bimodal distribution along a particular acoustic dimension (i.e., the frequency of the third formant (F3)). That is, in natural speech, exemplars of /r/ cluster together at lower values of F3, whereas exemplars of /l/ cluster together at higher values of F3, with only a small degree of acoustic overlap between productions of /r/ and /l/. In contrast, in natural Japanese productions there is a unimodal cluster of sounds, called a flap, that overlaps with American English /r/ and /l/ (see Figure 4.1 for an

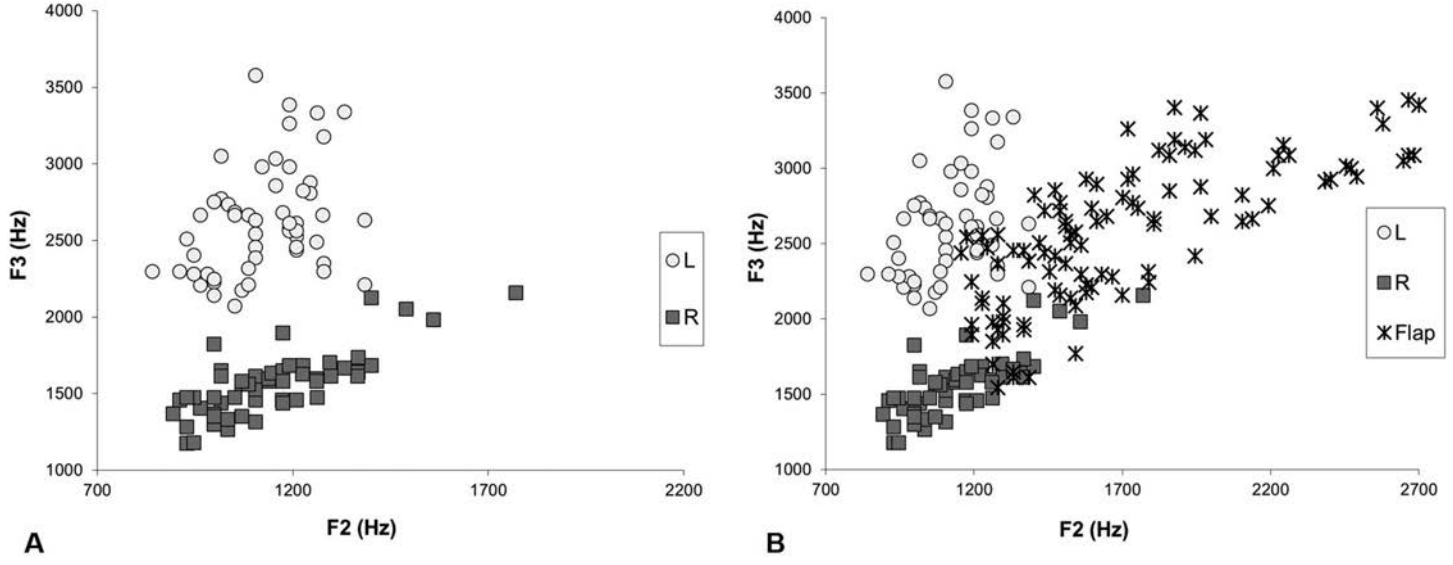



*Figure 4.1* Comparison of English speakers' productions for /l/ and /r/ (a) overlaid with Japanese speakers' production of the flap consonant (b).
*Source*: Lotto, Sato, & Diehl (2004).

example of natural productions of English /l/ and /r/, and the Japanese flap, from Lotto, Sato, & Diehl, 2004). Although both English- and Japanese-learning infants are initially able to discriminate English /r/ from /l/, by the time they are 11 months old, Japanese-learning infants have collapsed the English contrast into a single category, consistent with the distributional information found in their language (Kuhl et al., 2001). Thus, sensitivity to this type of statistical distributional information might account for perceptual narrowing observed in the first year of life.

Maye, Werker, and Gerken (2002) tested the prediction that infants are sensitive to distributional information by presenting 6- and 8-month-old infants with a bimodal or unimodal distribution during familiarization and then testing their subsequent speech perception abilities. They created a continuum of eight tokens between English /da/ and /ta/ (voiceless unaspirated stop) that varied in voice onset time, as well as F1 and F2 trajectory. In the bimodal condition infants heard a greater frequency of tokens at either end of the continuum, whereas in the unimodal condition the majority of the tokens were selected from the middle of the continuum (see Figure 4.2). This manipulation effectively simulated experience with languages that have two phoneme categories along a continuum (i.e., bimodal) versus languages that have a single phoneme category (i.e., unimodal). Following familiarization, only infants in the bimodal condition were able to discriminate the two endpoint tokens. This pattern of results suggests that experience with bimodal distributions may lead infants to form separate phoneme categories, whereas experience with unimodal distributions may encourage infants to collapse acoustic variation into a single category. In a conceptual replication of this work, Teinonen and colleagues (Teinonen, Aslin, Alku, & Csibra, 2008) found that visual speech information can also alter how infants assign distributional information to phonetic categories.

Across the first year, in addition to discovering the relevant sound categories of their native language, infants also become better at discriminating native-language phonemes (Kuhl et al., 2006; Narayan, Werker, & Beddor, 2010). In follow-up work, Maye, Weiss, and Aslin (2008) tested the prediction that distributional information also enhances phoneme discrimination, especially for contrasts that are initially difficult to discriminate. Again, infants were familiarized with either a unimodal or bimodal distribution and were tested on tokens from the endpoint of that distribution (i.e., /da/ and /ta/) or on a different contrast that varied along the same acoustic dimension (i.e., voice onset time, /ka/ and /ga/). Discrimination was only facilitated by experience with the bimodal distribution, for both the trained distribution and the novel contrast. These results suggest that infants can use distributional information to extract a specific

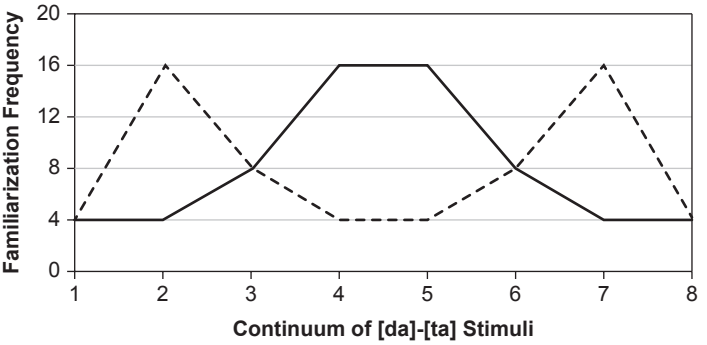



*Figure 4.2* Bimodal (dashed lines) and unimodal (solid line) sound distributions used in Maye, Werker, & Gerken, 2002.

acoustic feature (e.g., voice onset time), and generalize this knowledge to novel sound distinctions. Clearly, distributional information in natural language is much more complex than the distributions presented in the lab. However, if infants are also sensitive to the distribution of speech sounds found in natural language, this sensitivity may support phonological development.

Further support for the idea that infants learn their phoneme categories through a process of distributional learning comes from work by Anderson, Morgan, and White (2003) showing that infants home in more quickly on consonant contrasts that occur more frequently in their input than on those that are heard more seldom. Consistent with this, infants perceptually narrow in on native-language vowel categories more quickly than consonant categories (Polka & Werker, 1994). Indeed, languages tend to have fewer vowels than consonants, and thus individual vowels typically occur more frequently in the input. Infants being exposed to more than one language have the added challenge of differentiating distributional patterns both within and across their languages (see Chapter 16, this volume for further information about bilingual language acquisition). These findings support the idea that the sounds that are heard more frequently are learned more quickly, suggesting that infants are also attentive to distributional properties in natural language input.

Computational modeling work has aimed to further uncover how sensitivity to distributional statistics interacts with other learning processes to give rise to phoneme learning. Recent computational models have suggested that the competition between representations of similar speech sounds may be one way that distributional statistics are categorized into phonemes. For example, in modeling biologically plausible distributional learning for vowels Vallabha and colleagues (Vallabha, McClelland, Pons, Werker, & Amano, 2007) found that phoneme clusters emerge from experience with the environment through competitive Hebbian learning processes that strengthen often heard phonemes into clusters, and prune the connections to less often heard sounds. Taking a different approach, McMurray, Aslin, and Toscano (2009) modeled the developmental trajectory of phoneme learning and also suggest that competitive processes are vital to phoneme categorization. According to their model, early in development, phoneme categories are represented continuously, with little space between representations. However, with exposure to distributional statistics, and the addition of a winner-take-all competition mechanism, phoneme categories became sparse and more discrete across developmental time, mimicking distributional phoneme category learning. Together, these modeling studies suggest that distributional statistics interact with perceptual and neural competition mechanisms to drive the phoneme learning process.

Some research suggests that distributional learning abilities may begin to decrease around 10 months of age, when infants appear to pick up on distributional patterns only if they engage in sustained attention during familiarization (Yoshida, Pons, Maye, & Werker, 2010). Further, beyond 10 months listeners may require additional experience with distributional patterns to show learning (Yoshida et al., 2010; Maye & Gerken, 2000). This timeframe appears to be consistent with the trajectory of perceptual narrowing in infancy (Maurer & Werker, 2014) and may also coincide with infants' ability to begin to take advantage of word-level information, such as lexical items that contrast in a single vowel (e.g., *dog* vs. *dig*) or consonant (e.g., *cat* vs. *hat*) (i.e., minimal pair words) when learning overlapping phonetic categories (Feldman, Myers, White, Griffiths, & Morgan, 2013).

Nevertheless, being good at tracking distributional properties in natural language early in infancy may produce a cascading effect on subsequent language learning. Indeed, Kuhl and colleagues (Kuhl, Conboy, Padden, Nelson, & Pruitt, 2005; Tsao, Liu, & Kuhl, 2004) provide evidence that individual differences in how quickly infants home in on their native-language sound categories are related to later language outcomes. For example, Tsao, Liu, and Kuhl (2004)

found that infants' ability to discriminate vowels at 6 months predicted their productive vocabulary size at 13, 16, and 24 months. In a subsequent, larger-scale study, Kuhl and colleagues (2005) found that 7-month-olds' ability to discriminate native and non-native contrasts was negatively correlated, such that infants who are better at discriminating phonemes in their native language are worse at discriminating non-native contrasts. Additionally, performance on native and non-native contrasts predicted later language outcomes in opposite directions. Infants who were better at native-language phoneme discrimination showed larger productive vocabulary sizes at 18 and 24 months, longer mean length of utterance, and greater sentence complexity compared to the infants who were less good at discriminating native-language contrasts. Conversely, infants who showed better performance on non-native contrasts at 7 months had smaller productive vocabularies, smaller mean length of utterances, and less complex sentences when tested at 24 months.

Individual differences in speech perception skills also appear to be tied to language outcomes in atypical populations. For example, infants at familial risk for developing dyslexia show poorer phoneme discrimination at 6 months than age-matched controls (Lyytinen et al., 2001). Additionally, when tested 3 years later they produced shorter sentences and had smaller vocabularies. Longitudinal data from Boets and colleagues (Boets, Vandermosten, Poelmans, Luts, Wouters, & Ghesquière, 2011) also supports the link between speech perception skills and dyslexia; children who performed worse on a phoneme perception task in kindergarten or first grade were more likely to be diagnosed with dyslexia 2 to 3 years later. Taken together, these results suggest that early speech perception skills may influence later language outcomes in children with dyslexia (Banai & Ahissar, 2017; Boets et al., 2011; Lyytinen et al., 2001). Section 3 of this volume will provide a more in-depth review of language development in atypical populations.

Findings on individual differences from both typical and atypical populations do not directly test the relationship between distributional learning and subsequent language outcomes. However, they do suggest that infants who learn to differentiate meaningful from irrelevant sound variants at a young age continue to be more advanced language users in the second year of life and beyond. If distributional learning drives perceptual narrowing, it stands to reason that infants who are better distributional learners may ultimately be more skilled language users.

## Finding words in speech

A second, and likely concurrent, challenge infants face when learning language is finding words in continuous speech. Word boundaries in spoken language are not marked by silent pauses (Cole & Jakimik, 1980), and less than 10% of the words infants hear occur in isolation (Brent & Siskind, 2001). Yet, by their first birthday, infants can understand many words and are beginning to produce their first words. Although natural languages contain various cues to word boundaries, such as prosodic patterns, phonotactic regularities, and allophonic variations, these cues are, by and large, language-specific. Thus, to use these cues infants need to know how they pattern in words in their native language. How do infants segment the speech before they know much about the patterns in their native language?

One of the most prominent hypotheses is that infants may begin to discover word boundaries, and thus segment words from fluent speech, by tracking the predictability between syllables within words and across word boundaries (e.g., Aslin, Saffran, & Newport, 1998; Saffran et al., 1996). In natural language, syllables within words tend to be highly predictive, whereas across word boundaries syllables are less predictable because words can be combined in many different ways. This type of statistical regularity is referred to as forward transitional probability (TP) when the first syllable of a word predicts the occurrence of the next syllable.

$$\text{Forward TP} = P(Y|X) = \frac{frequency(XY)}{frequency(X)}$$

$$\text{Backward TP} = P(X|Y) = \frac{frequency(XY)}{frequency(Y)}$$

When a given syllable predicts the occurrence of a former syllable, the statistics is referred to as backward TP and may be especially informative at the phrasal level in some languages (e.g., in the phrase *the dog* hearing *dog* predicts the occurrence of *the*, but not vice versa). Both forward and backward TPs are types of sequential co-occurrence statistics, because the predictive elements occur sequentially. Mutual information is the extent to which syllables within words are informative about each other (Swingley, 1999; 2005), and thus is essentially a statistic that incorporates predictive information in both the forward and backward directions. Finally, syllables and words also differ in their base-rate frequencies (i.e., how many times they occur; Swingley, 2005). Corpus analyses reveal that all of these sources of information are available in the input and may provide a fairly reliable language-general cue to word boundaries (Swingley, 1999).

As mentioned in the introduction, seminal work by Saffran, Aslin, and Newport (1996) demonstrated that infants are actually quite good at tracking TP information to find word boundaries in artificial language materials, suggesting that infants may begin to break into the speech stream by tracking sequential statistics in their input. This finding has been replicated numerous times (for a review, see Krogh, Vlach, & Johnson, 2013; Romberg & Saffran, 2010). Artificial languages are useful for designing tightly controlled studies and establishing infants' computational abilities, but lack the complexity associated with natural language input. In an attempt to increase ecological validity, Pelucchi, Hay, and Saffran (2009a) created familiarization corpora where we manipulated the statistics within words in a natural language. The corpus comprised naturally produced, grammatically correct, and semantically meaningful Italian sentences. Importantly, four key target words were incorporated throughout the corpus. Two of the target words had a high TP (HTP; TP = 1.0) because the syllables that made up the words never occurred anywhere else in the corpus. The other two target words had a low TP (LTP; TP = .33) because their first syllable occurred in many other words throughout the corpus (thus, TP was low in the forward direction). All four of the words were phonotactically legal in both English and Italian, and had a strong-weak (i.e., trochaic) stress pattern characteristic of disyllabic words in both languages. Using procedures very similar to those of Saffran and colleagues (1996), we found that following just 2 minutes of familiarization, 8-month-old infants preferred listening to the HTP words, even though both HTP and LTP words had been heard an equal number of times (i.e., 18 times) in the speech stream. This work suggests that infants are able to track TP information even in complex natural speech and lends support for the idea that statistical learning may play a role in early speech segmentation. In subsequent work, we have found that not only are young infants sensitive to forward TP information, but they can also use backward TP to find words in naturally spoken Italian (Pelucchi et al., 2009b).

As infants gain experience with the prosodic and phonotactic patterns of words in their native language, they may come to rely less on sequential statistics to find words in speech, in favor of language-specific cues. And indeed, statistical learning may be one avenue through which infants learn these language-specific patterns (Thiessen & Saffran, 2003). For example, using artificial language materials, Thiessen and Saffran (2003; see also Thiessen & Saffran, 2007; Johnson & Jusczyk, 2001) found that earlier in development (~ 7 months), infants rely more heavily on TP information than on stress pattern cues for identifying word boundaries.

However, by 9 months infants appear to weigh syllable stress more heavily than TP information. Thus, as infants gain more experience with their native language, their ability to track statistical patterns in speech interacts with what they know about cues to word boundaries in their native language (see also Johnson & Seidl, 2009). Fortunately, language-general and language-specific cues to word boundaries tend to converge in natural speech, and infants appear to benefit from the combined cues (Christiansen, Allen, & Seidenberg, 1998; Romberg & Saffran, 2010). Indeed, in our tasks (see Pelucchi et al., 2009a, b), infants were presented with at least two cues to word boundaries – TP information and lexical stress – and these converging cues may have made it easier for infants to track TP in the complex natural language input. In our lab, we are currently testing whether infants can track TP information in natural language when the target words have a less familiar, iambic (weak-strong) stress pattern.

Statistical-sequential learning may also be supported by other cues present in natural speech. For example, although isolated words do not make up a large portion of input to infants (Brent & Siskind, 2001), they appear to benefit from isolated words when computing TP (Lew-Williams, Pelucchi, & Saffran, 2011). Isolated words also appear to selectively support long-term memory for statistically defined words recently segmented from fluent speech by 8-month-old infants (Karaman & Hay, 2018). Work with adults further suggests that when words' base-rate frequencies are scaled up to those found in natural speech, signature patterns of statistical learning are replicated and persist in long-term memory (Frank, Tenenbaum, & Gibson, 2013). Finally, 8-month-olds can combine known words and TP information to enhance their word segmentation (Mersad & Nazzi, 2012). Similar to our discussion of the role of distributional learning in phoneme acquisition, the extant data does not provide definitive evidence infants actually use their ability to track TP information in the service of learning their native language. However, demonstrations that infants can track TP over input that increasingly approximates natural language input suggests that statistical-sequential learning may indeed be related to speech segmentation.

The link between statistical-sequential learning and language acquisition is further supported by recent research by Jill Lany and colleagues (Lany, Shoaib, Thompson, & Graf Estes, 2018) and by work with atypical populations (for a meta-analysis on the relation between statistical learning and specific language impairment, see Lammertink, Boersma, Wijnen, & Rispens, 2017). Lany and colleagues (2018) measured 15-month-old infants' performance on both a standard speech segmentation task that requires infants to track TP information in fluent speech and a task that measures their lexical knowledge, with the prediction that the infants who are better at processing native-language input may also be better statistical learners. They found that infants who were faster to look at a familiar object after it was labeled also demonstrated a preference for high TP words following familiarization with an artificial language. These findings suggest an intimate relationship between infants' sensitivity to statistical cues in the input and how well they know words in their native language.

Research with atypical populations can also reveal the potential relevance of statistical-sequential learning for language acquisition. Interestingly, 8- to 20-month-olds diagnosed with Williams Syndrome, a genetic disorder that impairs cognitive functioning but leaves language functioning relatively intact, show no impairment in tracking sequential statistics in artificial language materials (Cashon, Ha, Graf-Estes, Saffran, & Mervis, 2016). Conversely, children with developmental language disorder (DLD; Bishop, Snowling, Thompson, & Greenhalgh, 2017) (sometimes also referred to as Specific Language Impairment; SLI), who demonstrate relatively intact cognition but impaired language, have been shown to have difficulty tracking sequential statistics in similar types of studies (Evans, Saffran, & Robe-Torres, 2009; see also a recent meta-analysis by Lammertink et al., 2017). Children with autism spectrum disorder (ASD), who tend

to show a great deal of variability in language skills (see Chapter 21, this volume), appear to be sensitive to sequential statistics in artificial language materials (Mayo & Eigsti, 2012), but not in natural language stimuli (Kovelman et al., 2015). Kovelman and colleagues (2015) suggest that the reduced sensitivity to rhythmic information in continuous speech seen in children with Autism may impair their ability to track TP information in natural language. Further studies that explore the relationship between individual difference in language skills within atypical populations and statistical-sequential learning abilities may bolster support for the importance of statistical learning in language development.

## Mapping words to meaning

A third challenge infants face when learning language is discovering how words map to meaning. Infants begin to associate words and objects early in development, and know the names of some concrete nouns as early as 6 months of age (Bergelson & Swingley, 2012; Tincoff & Jusczyk, 2012). However, there remain challenges in determining both what sound combinations form good labels, and which of the many possible referents in the environment a given label refers to. In this way, the learning challenge is often ambiguous on multiple levels.

To overcome the challenge of discovering potential word candidates, infants can rely on what they already know about sounds. For instance, nonsense words with features consistent with those present in the native language (e.g., high phonotactic probability, high neighborhood density, stress pattern) are treated as better candidate labels than those that do not follow such patterns (e.g., Gonzalez-Gomez, Poltrock, & Nazzi, 2013; Graf Estes & Bowen, 2013; MacKenzie, Curtin, & Graham, 2012; Storkel, Bontempo, Aschenbrenner, Maekawa, & Lee, 2013).

There is also evidence that infants treat recently segmented sounds as good word candidates. For example, Graf Estes, Evans, Alibali, and Saffran (2007) found that 17-month-olds readily learn to map words segmented from an artificial language (TP = 1.0) to visual referents, but fail to map nonwords and part-words (TPs of 0 and 0.33, respectively). Moreover, we found a similar pattern of results with 17-month-olds when they were familiarized with a corpus of naturally produced Italian (Hay, Pelucchi, Graf Estes, & Saffran, 2011) – infants mapped high TP (HTP, TP = 1.0) words to novel objects, but failed to map low TP (LTP) words (forward and backward TP = .33).

In recent work from our lab, we are finding that when words are presented in carrier phrases (e.g., "Look at the casa"), older infants aged 22 to 24 months, map both HTP and LTP words to referents, but do so for different reasons. Like younger infants, older infants appear to map HTP words because of their strong internal sequential statistics. However, older infants appear to be mapping the LTP words because the syllables that compose those words are highly frequent in the corpus.[1] Thus, for older infants both sequential statistics (i.e., TP information) and syllable frequency statistics appear to feed into subsequent word learning. Interestingly, individual-differences data exploring the relationship between performance on our word learning task and vocabulary size support our findings that HTP and LTP words are mapped for different reasons; there were no significant correlations between vocabulary size and word learning for the HTP words, but there was a significant negative correlation between vocabulary size and word learning for LTP words.

In a more pared-down task that provided minimal referential support, with slightly younger 20-month-old infants, Shoaib, Wang, Hay, and Lany (2018) found that although, overall, infants did not show learning of either HTP or LTP words from a foreign language, performance was also correlated with their vocabulary size. Only infants with a smaller vocabulary successfully mapped the HTP words to meaning, suggesting that as infants gain native-language knowledge they become less

open to treating non-typical words as good object labels. Further, like in the work from our lab described above, infants with a larger vocabulary showed a tendency for more success in mapping LTP words to referents. Together, these studies not only suggest that HTP are words treated as candidate object labels, but highlight how taking an individual-differences approach to studying statistical learning may reveal differences in underlying processes (for additional discussion of the relationship between individual differences in statistical word learning and vocabulary development, see also Lany & Saffran, 2010; 2011; Lany, 2014).

Although Mainela-Arnold and Evans (2014) have demonstrated that the ability to track TP information is related to phonological (but not semantic) processing in both children with and without DLD, to our knowledge there is only one study that has investigated how statistical-sequential learning feeds into subsequent word learning with atypical populations. Haebig, Saffran, and Weismer (2017) tested school-aged children (8 to 12 years old) with typical development, ASD, and DLD on their ability to segment words from an artificial language, map words to referents without any pre-familiarization, and a combination of the word segmentation and word mapping tasks. Although children with DLD appeared to perform at chance on the word segmentation task, they benefited most from experience with the sequential statistics in the combination task. Children diagnosed with ASD who did not have any language impairments performed similarly to typically developing children on all tasks. However, ASD children with language impairment appeared to struggle with the word mapping task, but only if they did not get prior experience with the words in the artificial language. Contrary to expectations in the combination task, across all populations, children did not map statistically defined words (i.e., words with strong internal co-occurrence statistics) to referents more easily than nonwords (made of non-adjacent syllables from the corpus). One possible interpretation of these findings, based on recent data from our lab (see above), is that mapping of the nonwords may be driven by sensitivity to syllable frequency information in the corpus, although this interpretation is speculative.

The use of these types of combined word segmentation plus word mapping tasks raises the question of whether word learning in non-ambiguous situations only unfolds in a two-stage process, where sounds are first segmented (creating a meaningless proto-lexicon) and only then mapped to referents, or if the two processes can occur simultaneously. Cunillera, Laine, Càmara, and Rodríguez-Fornells (2010) showed that adults can segment words from continuous speech and simultaneously map them to objects (see also François, Cunillera, Garcia, Laine, & Rodriguez-Fornells, 2017). Further, using a modified statistical learning task, where infants were presented with statistically defined words (TP = 1.0) in short phrases, Shukla, White, and Aslin (2011) showed that infants as young as 6 months can simultaneously extract words (TP = 1.0) and map them to visual referents when those words were aligned with prosodic cues, but fail to do so when statistics and prosody are misaligned. The authors argue that young infants may combine both statistical cues (e.g., TP) and native-language perceptual cues (e.g., prosody) to overcome simultaneous segmentation and mapping challenges.

The uncertainty with which labels and referents co-occur in natural environments poses a unique challenge for word learning (Quine, 1960). Uncertainty can take many forms. For example, the likelihood that labels and referents will co-occur can vary, and infants appear to be sensitive to these co-occurrence statistics. For example, Vouloumanos and Werker (2009) found that 18-month-olds succeeded at learning label-referent pairs when labels were consistently applied to a single referent (100% of the time) and when labels were applied to a given referent the majority of the time (i.e., 80%). Infants failed to map label-referent pairs when the co-occurring probability was much lower (i.e., 20%). These results suggest that the strength of co-occurrence between labels and referents may be an important statistical cue for word learning.

In natural learning environments, the presence of multiple labels and referents creates another source of uncertainty. A number of studies over the past decade have investigated how statistical cues may help children and adults overcome this challenge (for a review see Yu & Smith, 2012a). For instance, Smith and Yu (2008) presented 12- and 14-month-old infants with ambiguous naming events. On any given trial infants saw two referents and heard two labels; however, the mapping between individual labels and referents was not transparent. Infants could only discover label-referent pairs by comparing co-occurrences across trials (see Figure 4.3), a phenomenon known as cross-situational statistical learning, and both age groups succeeded in the task. Furthermore, even when labels contain phonetic overlap (e.g., *bon-ton*, *deet-dit*) – a common characteristic of words found in natural speech – infants at 12, 15, 17, and 20 months of age appear to map referents to labels across trials (Escudero, Mulak, & Vlach, 2016). These basic findings have been replicated in 5- to 7-year-olds (Suanda, Mugwanya, & Namy, 2014) and with children diagnosed with ASD (McGregor, Rost, Arenas, Farris-Trimble, & Stiles, 2013).

Individual-differences research suggests that cross-situational statistical learning may be related to other measures of cognitive and language development in typically developing children. For example, Scott and Fisher (2012) found that while 30-month-olds with larger vocabularies successfully mapped both transitive and intransitive verbs to actions across situations, infants with smaller vocabularies were only able to map the intransitive verbs, suggesting that cross-situational statistical learning abilities may be related to vocabulary development. In another study, Smith and Yu (2013) used a block design to test how 12- and 14-month-olds' attentional patterns affected cross-situational statistical learning and found that while learners and non-learners did not differ in how much attention they paid during training (differing from a previous report by Yu & Smith, 2011), learners had significantly larger receptive and productive vocabularies when compared to non-learners.

Using a similar approach, Vlach and Johnson (2013) explored the role of memory in cross-situational statistical learning with 16- and 20-month-olds, by presenting half of the label-referent pairs in a consecutive manner, and the other half interleaved across blocks (see Figure 4.4). Twenty-month-olds learned both the consecutive and interleaved pairs, whereas 16-month-olds only learned pairs presented in consecutive order. Neither attentional patterns nor vocabulary size predicted learning. In a follow-up study, designed to examine the relationships among

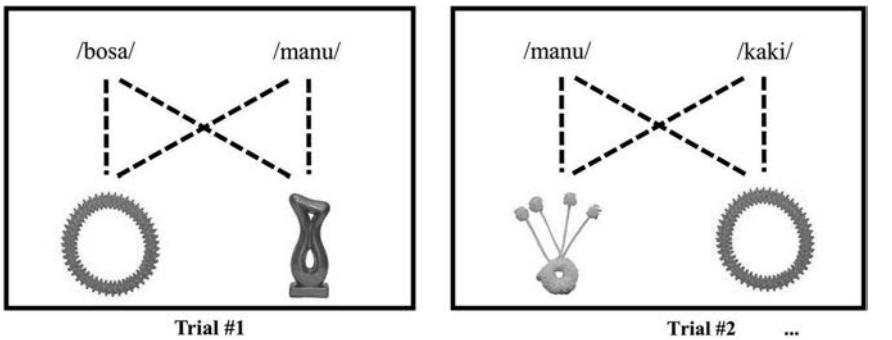



*Figure 4.3* Two trials from a cross-situational learning task. Dashed lines indicate possible relations between labels and referents. For instance, by tracking label-referent co-occurrence across trials infants could map /manu/ to the circular object.

*Source*: The pictures from this example come from Horst and Hout (2016), and the words come from Smith and Yu (2008).

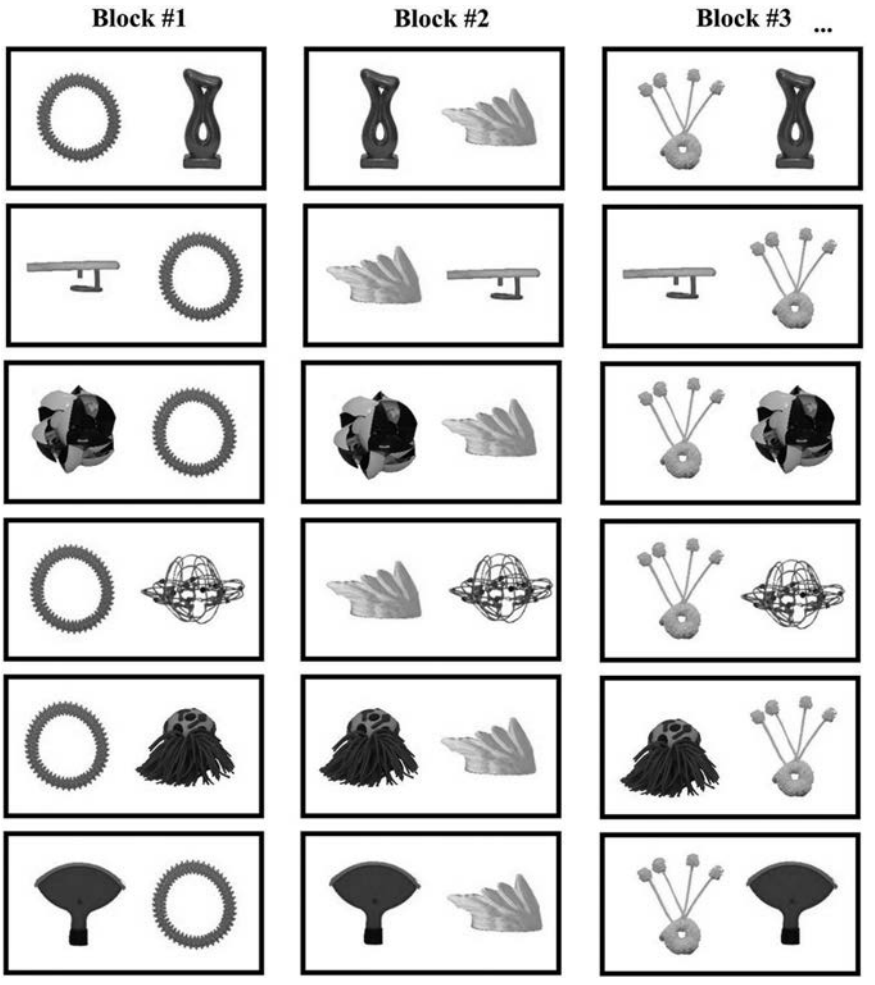



*Figure 4.4* An example of the type of block design used by Vlach and Johnson (2013). On each block, one pair is always repeated consecutively across trials (massive presentation), and the other pair is presented once in each block (interleaved presentation).

*Source*: The pictures from this example come from Horst and Hout (2016).

age, receptive vocabulary, and recognition memory in cross-situational statistical learning, Vlach and DeBrock (2017) tested children between 22 and 66 months of age. They found that while vocabulary size and recognition memory both predicted learning, recognition memory was a stronger predictor of performance. Child age was not predictive of learning. Together these studies suggest that cross-situational statistical learning abilities may be related to the development of both language and non-linguistic cognitive skills.

Smith, Yu, and collaborators (Pereira, Smith, & Yu, 2014; Smith, Yu, & Pereira, 2011; Smith, Yu, Yoshida, & Fausey, 2015; Yurovsky, Smith, & Yu, 2013) have proposed a new approach for framing the uncertainty problem under natural contexts. By taking infants' egocentric vision into account (using lightweight head-mounted cameras), researchers have begun to understand how

cross-situational statistical learning becomes constrained by infants' own interactions with the world. For instance, 16- to 18-month-old infants disambiguate visual scenes in the laboratory by holding and looking at only one object at a time, and their parents, in turn, often name the object during these optimal learning moments, promoting word learning (Yu & Smith, 2012b). Further, even in highly cluttered natural visual and auditory learning environments, a limited set of objects fill the infant's visual field during specific activities (e.g., table, shirt, chair, and bowl during meal time) (Clerkin, Hart, Rehg, Yu, & Smith, 2017). These more constrained contexts offer ideal word learning opportunities, and indeed many of these activity-specific words are found in infants' early vocabularies (see also Bergelson & Aslin, 2017; Roy, 2009). Chapter 7 (this volume) delivers a detailed analysis of this research and its insightful advancements.

## Learning rudimentary grammar

In addition to discovering sounds in language, finding words in speech, and mapping words to meaning, infants also face the challenge of learning the grammatical patterns in their native language. For example, not only do infants need to learn syntactic categories (e.g., which words are nouns, verbs, etc.), but they also need to learn how relational categories (e.g., subject, object) are ordered in their native language (e.g., is their language a subject-object-verb (SOV) language or a subject-verb-object (SVO) language?). For example, infants need to discover how past, present, and future tenses are used across non-adjacent (or long-distance) sequences (e.g., *Tomorrow* he *will* work; she *is* play*ing*), where there is an intervening element that is often irrelevant to the tense marking (e.g., *he* and *play* from the examples above). Importantly, learning grammar requires infants to be able to generalize to novel exemplars (e.g., she *is* glerp*ing*). Research has shown that infants can track multiple forms of statistical information (e.g., frequency, co-occurrence, sequential statistics, non-adjacent dependencies, etc.) and can use this information to solve many of these higher-order grammatical challenges found in language.

Early attempts to investigate the role of statistical regularities in the acquisition of rudimentary grammar were focused primarily on how infants learn word order patterns. Although in some languages word order is not particularly relevant (e.g., Turkish, Farsi), in other languages (e.g., English, Dutch) the placement of words can significantly affect the meaning of sentences (e.g., *I had my car cleaned* vs. *I had cleaned my car*). In one study, Gómez and Gerken (1999) exposed 12-month-old infants to a 2-minute familiarization with an artificial language generated by a finite-state grammar (see Figure 4.5), where some word sequences were more predictive than others. At test, not only were infants able to discriminate grammatical from ungrammatical strings based on their predictiveness, they were also able to generalize the learned grammatical patterns to novel exemplars (see Gerken, 2006, for evidence that the specific structure of the distributional information can lead to broad versus narrow generalization of grammatical patterns). Further, using a somewhat simpler design, Marcus and colleagues (Marcus, Vijayan, Rao, & Vishton, 1999) have demonstrated that infants have the ability to generalize abstract "rule-like" grammatical patterns by 7 months.

Statistical learning is a dynamic process – much as the output of word segmentation can be the input for word learning (Graf Estes et al., 2007; Hay et al., 2011), recently segmented words also feed into learning about word order. Saffran and Wilson (2003) presented 12-month-old infants with an artificial language where words (TPs within words were 1.0, while TPs across word boundaries were 0.25) were organized according to a simple finite-state grammar, and the infants were tested on their ability to discriminate novel grammatical from ungrammatical strings. In order for infants to learn which word orders were permissible in the language, they first had to track TP information to discover which sound sequences formed words. Critically,

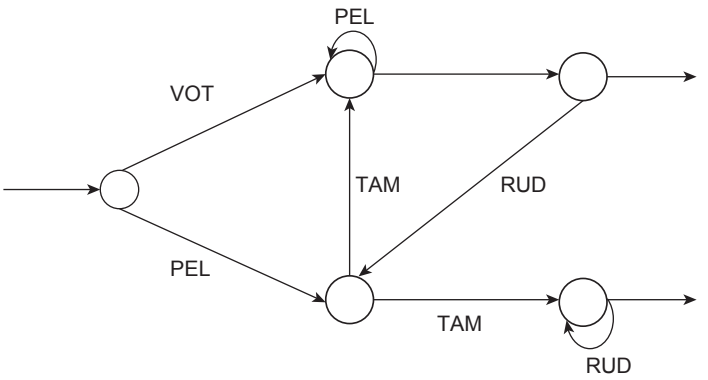



*Figure 4.5* Finite-state grammar used by Gómez and Gerken (1999). Strings start on the far left and proceed through the system in the direction of the arrows (e.g., VOT PEL JIC RUD TAM RUD represents a grammatical string).

*Source*: Gómez and Gerken (2000).

the TP between syllables was identical in both sentence types, and so they could not be discriminated based on TP information alone. Results showed that infants were able to differentiate grammatical versus ungrammatical strings, suggesting that their ability to track TPs across syllables to find words subsequently allowed them to track word order information.

Infants' sensitivity to distributional properties in grammatical relations might also help them learn abstract syntactic categories (e.g., determiners, adjectives, nouns, verbs). For example, if English-learning children learn that determiners *the* and *a* precede nouns but not verbs, whereas auxiliaries like *was* and *is* precede verbs but not nouns, then they should be able to make inferences about the syntactic categories of novel words. Thus, learning abstract syntactic categories may play an important role in grammatical development because they can support generalization to new utterances. Corpus analyses reveal that the same syntactic categories tend to appear in highly overlapping distributional contexts, or "frequent frames" (Chemla, Mintz, Bernal, & Christophe, 2009; Mintz, 2002; 2003); however, learning those categories by tracking distributional information alone can be very difficult for infants (Gerken, Wilson, & Lewis, 2005; Gómez & Lakusta, 2004; but see Lany & Saffran, 2011).

Importantly, in natural languages, words and their syntactic categories are marked not only by distributional cues but also by phonological and semantic cues. For instance, in English, nouns tend to both have a strong-weak stress pattern and occur after determiners *the* and *a*. To investigate the role of correlated cues in the acquisition of syntactic categories, a number of studies have used an *aX bY* type of artificial language that consists of nonsense word categories *a*, *b* (e.g., similar to determiners *the* and *a*) and categories *X*, *Y* (e.g., similar to categories like nouns and verbs). In these artificial grammars, *a* category is paired with *X*, and *b* category is paired with *Y*, but not vice versa, similar to the types of co-occurrence relationships described above for English syntactic categories. For example, using an *aX bY* paradigm, Gómez and Lakusta (2004) found that 12-month-olds were able to form categories by associating the distributional information of *a* and *b* words with a particular phonological feature of *X* and *Y* words (i.e., *X* words were monosyllabic and *Y* words were disyllabic). In another study, Lany and colleagues (2017) found that at 15 months, infants' ability to track these types of correlated cues in artificial language materials is related to individual differences in how efficiently infants process familiar words in their native language.

In another series of experiments, Lany and Saffran (2010) sought to investigate whether these types of correlated cues also facilitate the grouping of words into categories and subsequent mapping of those words to different categories of referents (e.g., animals vs. vehicles). Twenty-two-month-old infants were familiarized with an *aX bY* language where either *a* words (*ong* and *erd*) predicted two syllable words (e.g., *coomo*, *loga*) and *b* words (*atl* and *ush*) predicted one syllable words (e.g., *deech*, *jic*), or a control condition where *a* and *b* words each predicted one and two syllable words. Instead of testing infants on novel grammatical versus ungrammatical strings, infants went directly into a label-referent mapping task where *aX* sequences were paired with referents from one lexical category (e.g., animals) and *bY* sequences were paired with referents from another lexical category (e.g., vehicles). Infants learned individual referents and lexical categories when distributional and phonological cues were correlated (i.e., co-occurrence and number of syllables), and successfully generalized untrained *aX* and *bY* sequences to novel exemplars of the referent categories. Infants failed to learn when the cues were not correlated during familiarization even though they received the same experience during label-referent training. In a subsequent study, Lany and Saffran (2011) found that infants with more advanced vocabulary and grammatical skills (as measured by parental report) could use distributional cues alone to identify a novel referent from the learned category (i.e., upon hearing an *a* word infants would look at the novel exemplar of an animal), but they could not use phonological cues alone (i.e., when hearing an untrained two syllable word they failed to look at the novel animal exemplar). The reverse pattern was found for infants with less advanced vocabulary and grammatical skills (Lany & Saffran, 2011; see also Lany, 2014). This set of findings suggests that infants track correlations among distributional, phonological, and semantic information when learning words. They also indicate that these cues might be weighted differently depending on individual differences in infants' vocabulary and grammatical development.

Many of the studies that we have reviewed thus far have focused on infants' and children's ability to track adjacent dependencies (e.g., units that co-occur without any intervening information). However, natural languages also contain many sequential but non-adjacent dependencies, where the intervening information between co-occurring elements can vary (e.g., *is* writ*ing*, *is* read*ing*, *is* sing*ing*). Infants appear to be able to learn these types of morphosyntactic non-adjacent dependencies if there is sufficient variability in the intervening element (e.g., $AX_1B, AX_2B, \ldots, AX_{24}B$), but fail to learn when the intervening element only takes on a limited number of forms (Gómez, 2002; but see Vuong, Meyer, & Christinsen, 2016, for conflicting findings with adults). When variability in the intervening elements is low, learners may track individual items (tokens) in the input, but may fail to appreciate subtler patterns that occur between item types (e.g., the grammar). Conversely, Gómez (2002) suggests that high variability in the intervening elements decreases the co-occurrence statistics between adjacent elements, causing infants to redirect their attention from adjacent to more informative non-adjacent dependencies. Conceptual replications of this work, with both artificial and natural languages, have found that infants as young as 15 months appear to be sensitive to non-adjacent dependencies (e.g., Gómez & Maye, 2005; Lany & Gómez, 2008; van Heugten & Johnson, 2010). Further, although 12-month-olds appear to struggle learning non-adjacent dependencies, they appear to be able to use the adjacent relations to learn non-adjacent ones (Lany & Gómez, 2008).

Some languages also contain phonological non-adjacent dependencies. Unlike in English, in Turkish, vowels within a word tend to agree in their place of articulation, a feature called vowel harmony. For instance, the word for child (*çocuk*) is legal in Turkish because the /o/ and /u/ are both back vowels. Similarly, *kedi* (cat) contains all front vowels. Except for in borrowed words (e.g., *selam*, "hello", borrowed from Arabic), front and back vowels do not typically occur in the same words. A recent study by Mintz, Walker, Welday, and Kidd (2018) found that 7-month-old

English-learning infants can use vowel harmonic non-adjacent dependencies to segment words from fluent speech, suggesting that even without exposure to vowel harmony in their native language, infants are sensitive to these types of phonological non-adjacent dependencies early in life.

Although there are a number of studies that have explored individual differences in learning rudimentary grammar, including non-adjacent dependencies, and grammatical proficiency in adolescents and adults (e.g., Erickson, Kaschak, Thiessen, & Berry, 2016; Hsu, Tomblin, & Christiansen, 2014; Misyak & Christiansen, 2010; Misyak, Christiansen, & Tomblin, 2010; Plante, Gómez, & Gerken, 2002), to our knowledge, these relationships have not been as extensively explored in infancy and early childhood. One reason for the lack of focus on individual differences is because developmental studies on statistical learning have tended to use tasks that measure group level effects, where the aim has been to demonstrate that children of a certain age are able to learn certain types of statistical patterns. As interests have moved beyond proof of ability demonstrations, to exploring how individual differences in statistical learning map onto other types of perceptual and/or cognitive functioning, additional methodological considerations are necessary (e.g., see Siegelman, Bogaerts, & Frost, 2017, for pitfalls and solutions in studying individual differences in statistical learning). Certainly, the work by Lany and colleagues (Lany, 2014; Lany & Saffran, 2010, 2011; Lany et al., 2017; Shoaib et al., 2018) provides an exception to this focus on group level effects (see above). Further, while some recent individual-differences work by Kidd and Arciuli (2016) has found that children's ability to track statistics in a visual task is related to their grammatical knowledge (see also work by Conway, Pisoni, Anaya, Karpicke, and Henning (2011) on children with cochlear implants), much less is known about how tracking statistics in linguistic input is related to grammatical development. There have, however, been a few studies looking at individual differences in non-adjacent dependency learning in atypical populations. For example, a recent study by Iao, Ng, Wong, and Lee (2017) demonstrated that Cantonese-speaking children with DLD show difficulties in learning non-adjacent dependencies. Similarly, Kerkhoff and colleagues (2013) found that 18-month-olds at familial risk for dyslexia have deficits in non-adjacent dependency learning, perhaps accounting for the characteristic delays in grammatical and phonological processing seen in children with dyslexia. Although these studies have not explicitly explored the role of working memory capacity in the learning of non-adjacent dependencies, the two are likely related (Santelmann & Jusczyk, 1998; but see Hsu et al., 2014). Further research on individual differences in rudimentary grammar learning in infancy and early childhood may strengthen our understanding of the variability seen in early grammatical development.

## Conclusions

In this chapter, we have reviewed some of the extant evidence that has accumulated, especially over the past 20 years, suggesting that infants are equipped with sophisticated computational abilities and can use them to learn many of the types of structures found in natural languages. Although the studies that we have presented have focused exclusively on infants' ability to track statistics in linguistic input, it is important to note that these abilities are not specific to either humans or speech. For example, evidence for distributional learning has been observed in other acoustic domains (e.g., music: Ong, Burnham, & Stevens, 2017), sensory modalities (e.g., vision: Duffy, Huttenlocher, & Crawford, 2006), and taxa (e.g., rats: Pons, 2006). Statistical-sequential learning has been demonstrated with visual (Fiser & Aslin, 2001; Kirkham, Slemmer, & Johnson, 2002), tactile (Conway & Christiansen, 2005), and non-speech auditory stimuli (e.g., Hay & Saffran, 2012; Saffran, 2003; Saffran, Johnson, Aslin, & Newport, 1999), and in a number of

species (rats: Toro & Trobalón, 2005; cotton-top tamarins: Hauser, Newport, & Aslin, 2001; and songbirds: Chen & ten Cate, 2015; Takashi, Yamada, & Okanoya, 2010). Finally, a number of different species demonstrate evidence of being able to learn non-adjacent dependency relations (songbirds: Chen & ten Cate, 2017; primates: Newport, Hauser, Spaepen, & Aslin, 2004; Sonnweber, Ravignani, & Fitch, 2015) and rudimentary grammar (cotton-top tamarins: Fitch & Hauser, 2004; Saffran, Hauser, Seibel, Kapfhamer, Tsao, & Cushman, 2008; songbirds: Gentner, Fenn, Morgaliash, & Nusbaum, 2006), although not all non-human animals appear to be able to generalize grammatical patterns to new exemplars (for a review see ten Cate & Okanoya, 2012). The degree of commonality underlying all of these findings remains unknown; however, modeling (e.g., Perruchet & Vintner, 1998; Thiessen & Pavlik, 2013; Thiessen, 2017) and neuroimaging studies (for a review, see Schapiro & Turk-Browne, 2015) are beginning to answer some of these questions.

Although we have provided ample evidence that infants can track statistical regularities in the lab, we would be remiss to ignore that null findings are also prevalent in the field. For example, within the segmentation literature, infants appear to have a difficult time tracking statistics across words with variable length (e.g., Johnson & Tyler, 2010, but see Mersad & Nazzi, 2012), or if they have the expectation that words are one length (e.g., two syllables) and then the words in the speech stream are another length (e.g., three syllables; Lew-Williams & Saffran, 2012). Further, according to two recent meta-analyses (Cristia, 2018; see also Lewis et al., 2018), the evidence for distribution learning of phoneme categories has not proven to be very robust, partially because a number of researchers have failed to replicate the original Maye, Werker, and Gerken (2002) study, and of the studies that have replicated it, many have had relatively small effect sizes.

Null effects and failure to replicate are perhaps not particularly surprising given that infant methodologies are sometimes fragile, as infants are typically provided with very short periods of exposure (e.g., often ~ 2 to 10 minutes) to the statistical structures they are subsequently tested on, only a subset of infants may show learning in a given study, and small sample sizes limit statistical power. Indeed, in one recent meta-analysis by Black and Bergmann (2017), incorporating 68 experiments, and data from 1,454 infants, there was an overall significant but small effect size across studies examining infants' ability to track TP information in continuous speech. These results suggest that although it is highly likely that infants do possess these computational abilities, there is a need for increasing the power and robustness of statistical learning studies.

Some of these replication issues may also derive from the fact that much of the developmental work on statistical learning has relied exclusively on offline measures, which typically measure novelty versus familiarity preferences based on looking time differences during a post-familiarization phase. Kuppuraj and colleagues (Kuppuraj, Duta, Thompson, & Bishop, 2018) argue that these offline measures may confound effects of encoding and memory, use testing procedures that may interfere with the statistics of the initial encoding, and fail to capture how statistical regularities are tracked over time. Although online measures have been successfully and reliably used to study statistical learning in adults (e.g., Batterink & Paller, 2017; Kuppuraj et al., 2018; Misyak, Christiansen, & Tomblin, 2010), many of the common forms of infant methodologies do not lend themselves well to collecting online measures (for an exception see Romberg & Saffran, 2013). Finally, large-scale, multi-lab replication efforts, such as those outlined in the various ManyBabies projects (e.g., Frank et al., 2017), will ultimately help researchers to better understand the robustness of a variety of developmental phenomena, including statistical learning.

Although laboratory studies have revealed a great deal about infants' computational abilities, they do not demonstrate that infants actually use these abilities in the service of learning language. And indeed, given currently available methodology, proving this relationship will likely

be quite difficult. Throughout this chapter, however, we have reviewed studies exploring how individual differences in statistical learning might be related to individual differences in language proficiency, in both typical and atypical populations. While most of this work does not provide direct evidence that statistical learning drives language acquisition, and indeed we would never claim that statistical learning is the only avenue through which infants learn language, it does support the hypothesis that statistical learning and language learning may be related. Further, dissociations across different atypical populations (e.g., relatively intact language and statistical learning abilities in infants with Williams Syndrome (Cashon et al., 2016), but relatively impaired language and statistical learning in infants with DLD (Evans et al., 2009)) also support the hypothesis that statistical learning and language acquisition may be interconnected.

Given the evidence for a connection between statistical learning and language learning it is not surprising that there are a number of recent recommendations for interventions for clinical populations that build on statistical learning approaches. While some interventions have relied solely on graded approaches, where training begins with simplified input that gradually increases in complexity, those built on statistical learning approaches have emphasized the importance of implicitly providing patients with the types of variability and complexity found in natural language input from the outset (e.g., Alt, Meyers, & Ancharski, 2012). Consistent with this idea, Plante and colleagues (Plante et al., 2014) found that the variability of exemplars used by clinicians, rather than the number of repetitions of a single token, helped children with DLD learn grammatical morphemes (e.g., plural marker *s*, past tense *ed*) in a conversational recasting task (see also Leonard & Deevy, 2017). Researchers and clinicians should continue to consider interventions aimed at helping children extract statistical patterns in the input as a potential first step in improving language outcomes in vulnerable populations.

In addition to individual-differences research, another approach to addressing the question of whether and how infants use their computational abilities for language learning outside the laboratory involves presenting infants with more naturalistic learning challenges. In our lab, we have taken a number of approaches to increase the ecological validity of our measures. First, we tend to study statistical learning using complex natural language materials (i.e., Italian: Karaman & Hay, 2018; Hay et al., 2011; Pelucchi et al., 2009a, 2009b). Further, we have explored how statistical learning feeds into subsequent word learning (e.g., Hay et al., 2011; Shoaib et al., 2018) and how statistical learning might support long-term memory in infants (e.g., Karaman & Hay, 2018). Finally, we are currently examining both the robustness and specificity of statistical learning, by testing infants in more naturalistic/noisy listening environments. As we are able to demonstrate that infants' computational abilities stand up to the challenges inherent to language learning outside of the lab, we will be able to further elucidate the potential role for statistical learning in language development.

## Note

1 In order to lower the TP of the LTP words in both the forward and the backward direction, both the first and second syllables of the LTP words were presented throughout the corpus. Thus, while infants heard the syllables of the HTP words a total of 18 times, they heard the syllables of LTP words a total of 54 times each – 18 times in the LTP words themselves and then an additional 36 times throughout the corpus.

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# 5

# COMPUTATIONAL AND ROBOTIC MODELS OF EARLY LANGUAGE DEVELOPMENT

## A review

*Pierre-Yves Oudeyer, George Kachergis, and William Schueller*

### The role of computational and robotic models of language development[1]

Language involves a multitude of components interacting in complex ways in parallel and within several scales of time and space. There is the developmental timescale of the growth of an individual person, the glossogenetic or cultural timescale of the evolution of cultures, and the phylogenetic timescale of the evolution of species. Within the developmental timescale, ranging from moment-to-moment learning to years-long processes, multiple brain circuits interact with a multi-part body situated in a complex environment, and in various kinds of situations determining a diversity of information flows. Even though each of these levels and components needs to be studied independently in order to reduce the complexity of the problem, it is also fundamental to study their interactions. The sciences of complexity have taught us that in many natural systems, there are global phenomena that are the result of local interactions between components, but where individual study of these components would not allow us to see the global properties of the whole combined system. Many of the properties of language are probably not directly encoded by any of the components involved, but are the self-organized outcomes of the interactions of the components.

### *Language development as a dynamic system*

These self-organizational phenomena are often difficult to understand or to foresee intuitively, and hard to formulate in words. This is why research into language development today leverages computer science, mathematics, and robotics to provide complementary methods to developmental psychology and neuroscience. These fields provide methods to build operational models of the interactions between the components involved in language, conceptualized as a complex dynamic system (Elman, 1995; Steels, 1997; Smith & Thelen, 2003; Beckner et al., 2009; Thomas et al., 2016; Samuelson et al., 2017; Oudeyer, 2018a). An operational model is one which defines the set of its assumptions explicitly and formally, and then computes or simulates the consequences of these assumptions, proving that a particular set of conclusions is entailed. Such formalization forces researchers to make explicit all mechanisms and details of a theory, providing

opportunities to identify gaps, as well as to do synthetic experimentation with computers and robots to test their plausibility, to understand better their implications, and to generate predictions or new hypotheses. There are several kinds of models. In particular, from the structural point of view, one can identify two broad families: analytical mathematical models and algorithmic models of the causal mechanisms of language formation, which include a particularly important sub-family of models that consider the central role of embodiment, and that will be called here "robotic" models (as we will see, they do not necessarily entail the use of a physical robot, but may use a simulated model of the body).

## *Analytical mathematical models*

A first class of models abstract a certain number of variables from the phenomenon of natural language development and express how these variables are related and how they change over time in the form of mathematical equations. Usually this comprises systems of coupled differential equations and makes use of the framework of dynamic systems theory, and sometimes statistical physics (e.g., Nowak et al., 2002; Loreto et al., 2012). When these models are sufficiently simple, their behavior can be predicted analytically and formally proved from their mathematical structure alone. However, the abstractions and assumptions on which such proofs are based are sometimes far removed from physical, cognitive, and social realities. Moreover, the formal language of mathematical relations is not always very suitable for explaining processes at work in nature (or in culture).

## *Algorithmic models*

A second class of models focuses on the processes of language morphogenesis: these models are formulated in terms of algorithms. These algorithms are themselves expressed, in practice, using computer programming languages. Using this kind of formal language to describe a natural or a cultural process has two solid advantages. First, the great expressivity of these languages lets them formulate highly complex processes concisely (Dowek, 2011). Second, in the case of phenomena whose behavior is very difficult to predict analytically from a series of equations, it can be possible to calculate this behavior automatically through simulation. The programs can be run on computers in what is a simulation of a morphogenetic process, and researchers can observe how the simulated system behaves with different parameters. In research on language development, this approach often involves building artificial systems in which individuals (their bodies, brains, and behavior), their interactions, and their environment are modeled by programs. A large share of models have emphasized the modeling of the processes of language representation and learning, and can be distinguished along several dimensions described in the next three paragraphs: numerical vs symbolic, supervised vs unsupervised vs reinforcement learning, normative vs heuristic models.

## *Learning numerical, symbolic, or hybrid representations*

Some models represent language knowledge using strings or structured sets of symbols, such as in models of grammatical learning where sentences are represented by hierarchical trees of symbolic categories. Other models represent linguistic knowledge as sets of numbers, organized in vectors, matrices, or neural activities. For example, the discovery of invariants and associations in a multimodal flow of speech words and images can be achieved using techniques like non-negative matrix factorization (Driesen et al., 2009; Mangin et al., 2015). Another large

family of models considers numerical connectionist representations, in a family of models called connectionist modeling (Westermann & Twomey, 2017). Connectionist models rely on simplified models of neural circuits and their interactions, and most often the structure of the artificial neural network is specified by the modeler, and the weights of connections among artificial neurons are adapted during a simulated learning process. For example, some models of speech sound acquisition use artificial neural networks to simulate the acquisition of sensorimotor representations enabling an individual to learn to produce the speech sounds of its environment (Warlaumont et al., 2013). Some models combine connectionist and symbolic representations, such as models of various forms of syntactic processing where symbolic sequences of letters or words are fed into a neural network that learns to predict associated symbolic outputs such as word boundaries, syntactic categories, or semantic parse trees (Elman, 1990; Westermann & Twomey, 2017; Dupoux, 2018).

### *Supervised, unsupervised, or reinforcement learning*

Models of language acquisition leverage different types of learning processes as classified by machine learning theory. The first form of learning is supervised learning, where the model learns by observing inputs (e.g., an image of an object) and associated outputs to be predicted (e.g., the name of the object), trying to discover the regularities between these inputs and outputs to improve its predictions or classifications. Self-supervised learning is a specific form of supervised learning where the output is not provided by a teacher, but is directly observed in the environment by the learner (e.g., the input could be one modality of observations, and the output another modality which the learner learns to predict from the first modality). Unsupervised learning is another form of learning where inputs are not matched by target outputs, but rather the learning mechanism attempts to discover regularities in the underlying structure of the input distribution (e.g., clustering words according to the similarity of the contexts in which they appear). Finally, reinforcement learning is a form of learning where the learner attempts to learn a (context-dependent) behavioral policy that maximizes a reward expressed in the form of a scalar feedback. Hence, the learner is not provided examples of correct behaviors, but rather its behavioral attempts receive a score of fitness that it tries to improve. For example, some models of speech learning use an intrinsic reward measuring the saliency of sounds to drive the learning of vocalizations (Warlaumont, 2013), and some other models use an extrinsic reward measuring task completion to drive the acquisition of sentence interpretation in joint task contexts (Daubigney et al., 2012).

### *Normative or heuristic models of learning processes*

Another dimension of importance in the landscape of models of learning and representational mechanisms is the normative/heuristic distinction. One approach that has been very fruitful has been to model the child language learner as a Bayesian and/or rational learner which optimally infers structures from observed data and from a priori knowledge expressed in the form of probabilistic priors (Chater & Manning, 2006; Tenenbaum et al., 2011). The advantage of such an approach, especially when expressed in the Bayesian framework, is that it forces one to express formally and in a simple mathematical language most of the model assumptions, and it provides principled mathematical tools to evaluate the goodness of fit of particular models to account for a body of empirical data. However, such an approach also has several drawbacks. First, a number of findings show that the human brain, and especially the child's brain, may often learn in non-optimal and non-Bayesian manners, using heuristic

inference and cognitive shortcuts, not using all information available, and prone to various forms of errors (Morewedge & Kahneman, 2010). There are actually a number of arguments showing the potential evolutionary selection of such heuristics in a rapidly changing environment with severe limits on cognitive and metabolic resources (Todd & Gigerenzer, 2000; Oudeyer, 2018b). Another drawback of normative Bayesian models is that they require prespecification of all possible observations, events, and models in order to be able to compute probabilities. Hence, by construction they do not address the question of how representations are learned (they only address the question of how certain representations are selected among existing ones), which is a fundamental question of language development (e.g., how do phonetic representations form? How are word meaning representations formed? How are syntactic categories formed? etc). Also, normative Bayesian models become computationally intractable if one aims to scale to real-world high-dimensional data (Bossaerts & Murawksi, 2017). For these reasons, another very large family of models relies on heuristic models of learning, ranging from connectionist approaches (Westermann & Mareschal, 2014; Cangelosi & Schlesinger, 2015; Twomey et al., 2016) to heuristic statistical learning (Saffran et al., 1996a, b; Mangin et al., 2015) or symbolic learning (Mealier et al., 2017; Spranger & Steels, 2012). The advantage of these models is their very large expressivity, their capacity to address the problem of representation learning (especially in connectionist approaches), and their capacity to combine different kinds of learning mechanisms in the same model. Also, these models have shown to scale better to complex real-world situations, as shown by their pervasive use in robotic models of language learning grounded in high-dimensional spaces of perception and action (Cangelosi et al., 2010). A drawback of these models is that they often contain many free parameters, and there is no principled unified statistical framework enabling one to compare in an unequivocal manner their goodness of fit to account for empirical data.

Beyond a view of the computational modeling landscape organized along the formal technical dimensions we just described, there are two other ways to structure this landscape. First, it is possible to classify models in terms of which stage(s) of infant language development they are focusing on. In this chapter, we are focusing on the models of early language development, ranging from vocal development to the onset of speech as a communication medium and to early word learning. Many other models in the literature have also focused on later stages of language development, with a large focus on the development of syntactic capabilities: for these works, we refer the readers to these excellent reviews: Chater & Manning, 2006; Monaghan & Christiansen, 2008; Yang, 2011; McCauley & Christiansen, 2014.

Another way to classify models is in terms of the general causal developmental mechanisms that they focus on. This is the approach we follow in this chapter, where we analyze models in terms of several of these general causal mechanisms: cross-situational statistical learning, embodiment, social interaction, self-organization of brain-body-environment couplings, intrinsic motivation, and the links between learning and evolution.

Many computational models of language learning focus largely on the learning mechanisms involved in mapping words to their intended referents, referred as the problem of cross-situational learning (see also Chapter 11, this volume). In other words, the focus is on the mechanisms used to detect regularities in language data, while simplifying models of the interaction with the environment, of how data is collected, and how this impacts the properties of data. For example, many works model the environment as a database of examples which are incrementally and randomly selected by the learner to train their learning mechanism (e.g., a database associating words with their potential meanings). We focus on models for learning meaning, but many of the issues we highlight are relevant for models of syntax learning as well.

## *Robotic models: embodiment, social interaction, and intrinsically motivated active learning*

However, as we will detail more in the sections below, the real-world environment, and the way it is perceived and acted upon by an active body, and through situated interaction with others, contains a lot of structure that can guide learning processes. This is why computational models of language development have in recent years been hybridized in implementations that combine the use of computers and robotics. These models, instead of representing the brain-body-environment system purely as computer algorithms, make use of programs running on computers that are embedded in physical robots. Here, only the "brain" is formulated algorithmically, while the body is modeled using mechatronic elements, and the environment approximates to humans' real environment (including interaction with social peers though human-robot interaction). Furthermore, the "brain" in these approaches is not simply viewed as a passive statistical learning system, but rather an intrinsically motivated and goal-directed system. This approach is currently at the heart of developmental robotics (Cangelosi & Schlesinger, 2015), where there is intense activity around the modeling of sensorimotor, cognitive, and social development (Oudeyer, 2010). Finally, beyond the body and motivational context, language development has also been analyzed from the perspective of its bi-directional interaction with cultural and phylogenetic evolution (Steels, 2003; Cangelosi et al., 2010).

## *Symbol grounding problem*

Building this kind of robotic model is interesting from several points of view. First, regarding language, it addresses the symbol grounding problem, in other words the fundamental problem of how symbols are grounded in the physical world. The problem here, so eloquently formulated by Stevan Harnad (1990), is understanding how the symbols commonly used for describing and modeling languages (such as words and grammatical rules) can become meaningful in the physical and social reality of a real organism. In particular, it involves a capacity to link the abstract world of symbols to the concrete world of numerical and chemical quantities that are perceived and manipulated by the brain and the body in context. It is hard to see how models that are purely algorithmic, implemented entirely on computers that at base represent the world in a symbolic, discrete way, might usefully inform any questions about symbol grounding. Hybrid algorithmic-robotic models, on the other hand, which by definition are at the edge between the symbolic and the physical worlds, are extraordinary tools for studying this problem (Steels & Kaplan, 2000; Steels, 2012). Here algorithmic models of language are confronted with physical and social reality, and whether or not there is an effective grounding of symbols – a strong constraint on the plausibility of these models – can be tested empirically.

## *Brain-body-environment dynamic interactions*

There is another very good reason for using robots. As Esther Thelen and Linda Smith, for example, have argued in their theory of development (Smith & Thelen, 2003), the formation of behavioral and cognitive structures results from dynamic interaction among the brain, the body, and the environment. The body and the environment, whose physical substrate gives rise to particular properties of structure generation, have a crucial role. Embodiment, that is to say the material composition and the geometry of a body and its sensorimotor system, can dramatically simplify the acquisition of certain behaviors. For example, Chen Yu and Linda Smith showed how geometrical hand-eye relations and the physical manipulation of objects

could create favorable situations for learning the meanings of first words (Yu & Smith, 2012). Thus, the body carries out physically a type of information processing, sometimes referred to as "morphological computation" (Pfeifer et al., 2007). In this context, robots make it possible to model mechatronically – in a straightforward, realistic way – interactions among the brain, the body, and the environment that would be far too complex or even impossible to model algorithmically. The section on the role of embodiment below provides several examples of robotic models studying this perspective. In other spheres, many other examples can be found today of robotic models being used to enhance understanding of animal and human behavior (Oudeyer, 2010), concerning such varied phenomena as navigation and phototropy in insects, control of locomotion in dolphins, and distinguishing between self and non-self in human infants, but also the impact of the visual system on the formation of linguistic concepts.

## Mechanisms of cross-situational learning

Beyond learning the sounds of a language (e.g., Feldman, Griffiths, Goldwater, & Morgan, 2013), and segmenting contiguous speech into words (e.g., Monaghan & Christiansen, 2010), infants face the daunting challenge of mapping words to referents. Each utterance from a caregiver might have any of a variety of intended meanings that can be difficult to discern in spite of cues such as gaze and pointing. A useful source of disambiguating information may be had if infants are able to track which words are frequently heard in conjunction with particular referents. If a given word and its intended referent co-occur repeatedly across a variety of scenes, and infants can track this conjunction to some extent, then the word's meaning may be learned cross-situationally. Such cross-situational learning is thought to be an important way for children to learn words with concrete referents (Smith & Yu, 2008; Pinker, 1989). Since most real-world situations contain many possible word-referent mappings, but time and attention are limited, learners likely use heuristics or strategies (implicit or explicit; learned or innate) to restrict the number of meanings they consider. Computational models of cross-situational learning have sought to discover the representations and mechanisms that people use to track and disambiguate word-referent co-occurrences.

Two dominant modeling approaches have emerged to account for cross-situational word learning: associative models and hypothesis-testing models. These accounts are discussed below with details of how they are typically compared to human learning behavior in short-term experiments. However, models of both types often make simplifying assumptions about the input (e.g., pre-segmented words and well-defined objects) that are unlikely to be met in the real-world language environment. Models proposed in developmental robotics use machine learning models with fewer assumptions about the input, but also have not yet been shown to scale to real-world input. Independently, a variety of simulation investigations have asked whether simple learning mechanisms can scale to acquiring a full-sized adult lexicon in a reasonable amount of time. For analytical purposes, these simulations often make unrealistic simplifying assumptions about the independence of learning each word, and about the sampling process by which words and referents are experienced.

Cross-situational word learning has been studied in infants (Smith & Yu, 2008), children (Akhtar & Montague, 1999), and adults. While it is assumed that many of the same word-learning mechanisms are operating in adults, it is important to note that cognitive abilities in infants and children are still developing. Adults are often studied because their greater attention span enables the use of more complex, extended designs. In a typical adult study, participants are asked to learn the referents of roughly 20 nonce words by watching a series of training trials. On each trial, learners see an array of two to four unfamiliar objects (e.g., sculptures) and hear

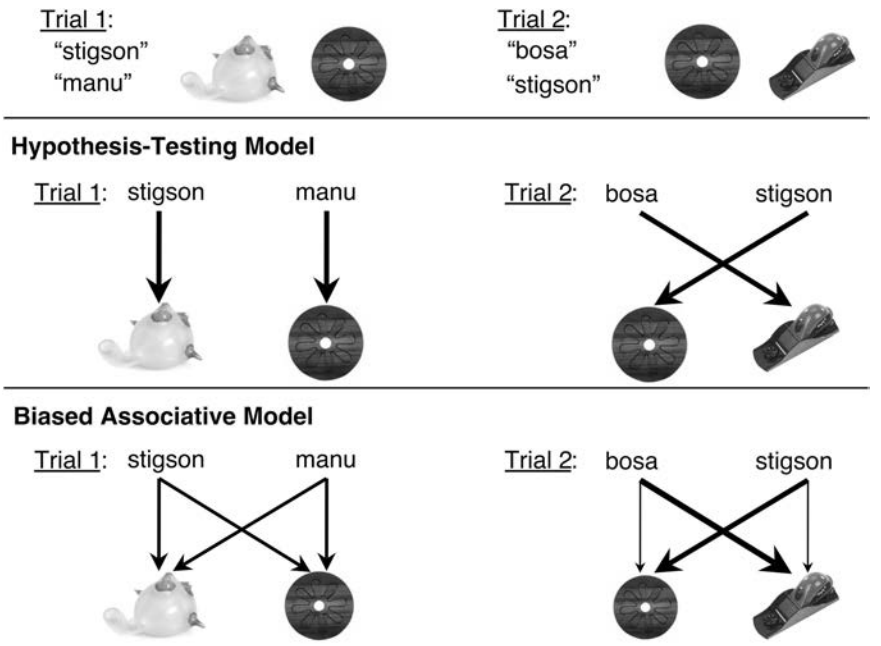



*Figure 5.1* Example of two cross-situational learning trials (top) from which three word-referent pairs might be learned, along with schematic representations that might be learned by a hypothesis-testing model (middle; e.g., propose-but-verify) that tracks a single hypothesized referent per word, and an associative model (bottom; e.g., the familiarity- and uncertainty-biased associative model) that attends to all co-occurring words and objects to some extent.

a corresponding number of pseudo-words (e.g., *stigson*, *manu*). See Figure 5.1 for an example of two cross-situational learning trials, from which an observer may learn three word-object mappings. Although each word refers to a single onscreen object, the referent of each pseudo-word is ambiguous on a given trial, because the intended referent is not indicated. In a typical learning scenario, participants might view each of 18 word-object pairings six times as they appear four at a time across 27 trials, for a total duration of several minutes (Yu & Smith, 2007; Kachergis, Yu, & Shiffrin, 2013; Suanda & Namy, 2012).

## *Hypothesis-testing models*

The hypothesis-testing theories view word learning as a problem of induction with an enormous hypothesis space that must be reduced by the learner applying a number of language-specific constraints in order to simplify the problem (Markman, 1992). In this view, infants generate hypotheses that are consistent with this set of constraints and principles. For example, the global principle (or bias) of mutual exclusivity (ME) assumes that every object has only one name (Markman & Wachtel, 1988). At a lower level, the fill-the-lexical-gap bias is proposed to cause children to want to find a name for an object with no known name (Clark, 1987; Merriman & Bowman, 1989). When given a set of familiar and unfamiliar objects, it has been shown that 28-month-olds assume that a new label maps to an unfamiliar object (Mervis & Bertrand, 1994). Similarly, the principle of contrast states that an infant given a new word will seek to

attach it to an unlabeled object (Clark, 1987). Fill-the-gap, ME, and contrast make many of the same predictions made by the more general novel name-nameless category principle (N3C), which states that novel labels map to novel objects (Golinkoff, Mervis, & Hirsh-Pasek, 1994). In order to be of aid to infant learners, such principles are thought to be either innate or developed very early in life (Markman, 1992).

The hypothesis-testing approach is used in the formal analysis of language acquisition (Gold, 1967; Pinker, 1979), stemming from inferential methods in the philosophy of science, with developmental theories built upon this rationale (Carey, 1978; Carey & Bartlett, 1978; Clark, 1987). A shared intuition among these approaches is that the multitude of co-occurrences available in the visual and auditory environment of the learner is far too complex to be tracked, stored, and updated (Gleitman, 1990; Gershkoff-Stowe & Hahn, 2007; Medina, Snedeker, Trueswell, & Gleitman, 2011; Trueswell, Medina, Hafri, & Gleitman, 2013). A model that exemplifies the hypothesis-testing approach is the propose-but-verify model (Trueswell et al., 2013), which assumes that only a single hypothesized referent is stored for each word, and that on further exposure to the word this proposal is recalled with some probability, and then either verified if the referent is present – increasing the future probability of recall – or discarded if the referent is absent (see Figure 5.1). In case the hypothesized referent is absent or fails to be retrieved, a new hypothesis is chosen from the currently available referents. This model accounts for adult word-learning behavior in some experimental contexts (Trueswell et al., 2013), but not in others (Kachergis & Yu, 2017). More sophisticated rule-based models of word learning scale well in some corpus-based applications (Siskind, 1996), but have not attempted to account for human behavior in experiments, or in real-world learning environments. A Bayesian model of cross-situational word learning makes binary word-referent hypotheses according to the global co-occurrence structure, combined with an a priori preference for a small lexicon (Frank, Goodman, & Tenenbaum, 2009). This model is able to learn small lexicons from child-parent interactions, based on transcribed speech and hand-coded representations of the visible objects. These models showcase the learning power of sparse, hypothesis-based representations in combination with rules and biases about which hypotheses to form.

## *Associative learning models*

In another view, word learning can be explained as a gradual accumulation in memory of all experienced co-occurring words and referents, perhaps relying on domain-general associative mechanisms rather than positing logic-based constraints or language-specific mechanisms (Smith, 2000; Regier, 2005; Kachergis, 2012). In general, these models accumulate associative strength between any co-occurring word and object, but the increment of a particular association can be weighted by factors such as prior knowledge (i.e., an already-existing association based on past co-occurrence), novelty, or uncertainty (the entropy of a word or referent's associations; see Figure 5.1). This online attentional shifting can allow associative models to show order effects such as highlighting (Kachergis, 2012), bootstrapping of low frequency word meanings when they appear in the context of known referents (Kachergis, Yu, & Shiffrin, 2016), and inference-like behavior much like a mutual exclusivity bias (Kachergis, Yu, & Shiffrin, 2012). These behaviors of the biased associative model emerge from the interaction of competing attentional biases to 1. strengthen already-strong associations and 2. attend to words or referents with uncertain (high-entropy) associations (Kachergis et al., 2012). Rather than using arbitrary associative strengths, some associative models maintain conditional probability distributions that are updated as new co-occurrences are observed (Fazly, Alishahi, & Stevenson, 2010).

The intuition behind associative learning models is that any words heard in a given context will impact the representation of the referents to some extent. While it may seem too difficult for a learner to track the associations between a word and not only its intended referent but its many distractors, the presence of the unintended associations both provides a sense of context (e.g., forks and knives often appear together) and serves as noise when learners are trying to retrieve the correct association. Associative models tend to be able to account for detailed behavioral effects found in experiments, including interactions of context diversity and word frequency (Kachergis et al., 2016) as well as response trajectories during word learning (Kachergis & Yu, 2017). Recent efforts to match detailed human learning trajectories across a range of experimental conditions have found that sampling versions of models – both Bayesian (Yurovsky & Frank, 2015) and associative (Kachergis & Yu, 2017) – best match human behavior by storing multiple (but not all possible) hypothesized referents for each word. It has been pointed out that simple hypothesis-testing (e.g., Medina et al., 2011) and simple associative accounts are at the endpoints of a continuum of sampling models (Yu & Smith, 2012). A growing family of models combine associative learning with online referent selection to achieve better fits to empirical data (e.g., McMurray, Horst, & Samuelson, 2012; Kachergis & Yu, 2017).

## *Developmental robotics models*

However, as mentioned earlier, both hypothesis-testing and associative models of cross-situational word learning usually operate on the pre-segmented words and objects that are assumed to be easily identified by adult learners in cross-situational learning studies (Yu & Smith, 2007; Kachergis et al., 2016; Suanda & Namy, 2012). Modeling these short-term experiments has yielded important insights into how people store and update particular word-referent associations (or hypotheses), but using pre-segmented words and objects that are distinct from each other and from the background may oversimplify the mapping problem. Real-world learning environments offer a stream of changing multimodal information, from which learners must extract regularities at the appropriate level. It may be that learners need to first learn phonemes, then words, and even word classes before being able to map the appropriate entities to referents. Similarly, learners may need to learn to segment the visual world into objects, properties, and actions before being able to map words to these entities. However, learners may be able to take advantage of regularities in the cross-modal representations of both auditory and visual information (and other modalities, even). This is the approach taken by developmental robotics researchers, who have investigated cross-situational word learning using machine learning algorithms that build shared, cross-modal representations of scenes and utterances, from which words and concepts can be extracted (Mangin, Filliat, ten Bosch, & Oudeyer, 2015; Chen et al., 2018). Such models suggest how it is possible to simultaneously learn different types of words, referents, and their associations without assuming separate processes for learning the structures within each modality (e.g., object detection or word segmentation). Nonetheless, these models are often tested in artificial experiments with small numbers of objects, utterances, and actions, and will require more effort to be scaled up to realistic situations and to be compared in detail to human word learners.

## *Large-scale simulations*

Efforts to understand whether cross-situational learning can realistically learn an adult-sized vocabulary come from simulation studies investigating simple learning mechanisms. Blythe, Smith, and Smith (2010) tested how quickly a logic-based fast mapping mechanism (that strictly

rules out any referents not currently present when a word appears – often resulting in one-shot learning) can be expected to learn the 60,000 words in an adult-sized vocabulary. The simulation showed that learning time for a full vocabulary using a fast mapping mechanism is well within reason, with 99% of the words learned by the time 940,000 words have been sampled (i.e., 142 words per day for 18 years). Simulations of a hypothesis-testing "guess-and-test" mechanism had learning times that were only 50% slower – requiring a still reasonable 214 learning episodes per day. However, these analytical estimates rely on making a variety of simplifying assumptions that likely impact the validity of these estimates. The assumptions made by Blythe et al. (2010) and others (Blythe, Smith, & Smith, 2016; Vogt, 2012) are: 1. a word is only heard when its meaning is present in the situation, 2. perception of words and situations is errorless, 3. every situation has the same number of possible referents, 4. each word maps to a single meaning, 5. learners know the space of meanings that are possible, and 6. words are assumed to be learned independently, meaning learners are expected not to be using even a mutual exclusivity bias. Many of these assumptions further simplify the learning problem, although, critically, some are not realistically plausible (e.g., words are often heard in the absence of the referent). Furthermore, the distributions of words, referents, and situations are independently randomly sampled in these simulations, rather than reflecting the skewed frequency distributions found in real-world speech and the nested structure found in natural scenes (Hidaka, Torii, & Kachergis, 2017). Future studies will need to consider long-term learning in simulations using more realistic learning mechanisms, as well as more realistic distributions of experience, with interdependent word learning.

## *The statistics of the language environment*

The exponential distribution of word frequency – with a few words appearing quite often, and the majority of words being vanishingly rare – has intrigued researchers for decades, but there is no consensus on the cause of it (Zipf, 1949; Piantadosi, 2014). The fact that many words are infrequently heard presents a difficulty for learning, as there will be few opportunities to learn these words and disambiguate their meanings. If referents also have an exponential frequency distribution, simulations predict that cross-situational learning will be orders of magnitude slower (Vogt, 2012). Much recent research has been focused on the distribution and structure of both the language input that children receive (Jones & Rowland, 2017; Hart & Risley, 1995) and the visual scenes they encounter. While we often think of visual scenes as offering a multitude of possible referents (Medina et al., 2011), analysis of recordings from head-mounted cameras on infants during free play has shown that infants often have only a single object dominating their view (Smith, Yu, & Pereira, 2011). The object filling their visual field is often being actively manipulated by the child or caregiver, and is likely to be mentioned. This finding seems to deflate the fabled complexity of the cross-situational learning problem. Importantly, the studies reviewed so far primarily address learning the semantics of words, largely ignoring syntax. However, a variety of models have been proposed to address the problem of learning syntax from experiencing sentences (e.g., Chang, Dell, & Bock, 2006; Freudenthal et al., 2007; Thomas & Knowland, 2014), as well as simultaneously learning semantics and syntax (e.g., a Bayesian model: Abend et al., 2017; a connectionist model: Li, Farkas, & MacWhinney, 2004). Due to space limitations we will not cover syntax learning in-depth, but many of the issues we identify for cross-situational word-learning models also apply to syntax learning models.

Rather than making assumptions about the learning process, some researchers have opted to use statistical waiting time models to investigate the impact of factors such as word length, word class, frequency in child-directed speech, and imageability to predict words' age of acquisition (Braginsky, Yurovsky, Marchman, & Frank, 2016; Hidaka, 2013; Mollica & Piantadosi,

2017). Fitted to children's vocabulary growth curves, these statistical models have been used to estimate the number of exposures and whether the rate of learning changes during development (Hidaka, 2013; Mollica & Piantadosi, 2017). Another approach is to use network theoretic models and semantic relatedness measures to model the growth process of children's vocabulary (Hills, Maouene, Riordan, & Smith, 2010). Much research has been devoted to characterizing individual variability in early word learning, finding that the amount of child-directed speech children receive correlates with vocabulary size and school readiness (Hart & Risley, 1995; Huttenlocher, Haight, Bryk, Seltzeer, & Lyons, 1991). Recent efforts to create large shared databases of early word-learning data such as WordBank (Frank, Braginsky, Yurovsky, & Marchman, 2016) and recordings of child-directed speech in the home such as HomeBank (VanDam et al., 2016) and CHILDES (MacWhinney, 2000) promise to unveil more about the structure and content of children's language input and its effects on vocabulary learning, and to serve as new goalposts and constraints for modeling efforts.

However, children do not learn only by passively receiving this audiovisual stream of information. Rather, they actively use their body to explore language and its referents, and they are active communicative partners, likely attending to and leveraging a variety of social cues to aid their learning. The following reviews how computational models have approached these active dimensions of language development.

## Robotic models: the role of embodiment, situatedness, and social interaction

Child language learners are distinguished from most artificial machine learning systems in that they are situated in a real-world physical environment with social peers. They are embodied in a very complex physical organism which filters information from the environment and affords certain kinds of actions on the environment. Also, children learn language in the context of achieving social and material goals. This situatedness and embodiment provides multiple forms of constraints that both define and guide language learning processes. Robotic models have been developed to study the roles and structures of these constraints. It is important to note that while robotic models focus on the physical and situatedness properties of the learner, they are not necessarily implemented with real-world physical robots. Indeed, many robotic models are entirely implemented in a virtual world with a simulator of the robot body and its physical/social interaction with the environment. The advantage of using simulated robotic bodies is that it facilitates systematic experimentation (gathering more statistics, larger exploration of the space of parameters). The drawback of simulated robotic models is that some aspects of the real world are difficult to simulate adequately, such as the natural variations (structured noise) in perceptual channels or social interaction with a (model) caretaker. Let us now give a few representative examples of (simulated or real-world) robotic models of language development.

### *Leveraging spontaneous structure from physics and body morphology*

Models of speech development have extensively studied the role of physical embodiment, due to the central role of the vocal tract and auditory system in phonetic and phonological learning (Stevens, 1972; Schwartz et al., 1997). The vocal tract is one of the most complex organs in the body, where a large number of muscles are used to continuously deform soft material parts such as the tongue, lips, or vocal folds (Boersma, 1998). In addition, the produced sounds are perceived by a complex auditory system with many non-linearities (Schwartz et al., 1997). One scientific challenge in speech learning is understanding how children learn to produce the speech sounds

of their native language given the high complexity of this sensorimotor system. From the point of view of control theory, this appears to be a conundrum given the high-dimensionality of the space and severe limits on time and energy available to the child for trying out vocal tract movements (Bernstein, 1967). So how can children learn canonical speech sounds already by the end of their first year? Several models have studied the natural dynamics of vocal tract movements, resulting from both mechanical coupling of movements and neural synergies among articulators. For example, Kelso (Kelso et al., 1986) took a dynamic systems approach, showing that random motor commands sent to the vocal tract produced already highly structured movements (hence speech sounds) due to the spontaneous structure resulting from these coupling dynamics. This enables one to show how learning speech sounds may amount to tuning some parameters of these spontaneous structures, which is much easier than learning from scratch and without the constraints of high-dimensional movements of the articulators.

## *Early words are grounded in concrete action and perceptual repertoires*

The role of embodiment has also been emphasized in several models of early word learning. A first obvious reason is that the first words children learn are concrete and directly related to their bodies, their actions, and their interactions with the environment (Bloom, 1995). Thus, the representation of the meanings of these first words, especially verbs and nouns, is intrinsically defined in terms of the action repertoire of children, and the way they perceive visually, haptically, auditorily, or spatially the objects around them. From this perspective, robotic models of bodies and their physical perception and action on the environment are a prerequisite for modeling the acquisition of the meaning of these early words, such as shown in models of learning of the names of shapes and colors (Steels, 2001; Roy, 2005), simple manipulative actions (Cangelosi et al., 2010), or spatial relationships among objects (Spranger & Steels, 2012).

## *Social scaffolding and imitation*

A second straightforward role of embodiment and situatedness, studied in robotic models, relates to social interaction and the non-verbal cues in the gaze, gestures, and discourse used by language partners (Rohlfing et al., 2016). These non-verbal cues enable joint attention, and more generally social guidance. Infants have been shown to attend to a variety of social and discourse cues, which may greatly simplify both speech segmentation and word learning. For example, the speech directed at infants by caregivers (e.g., *motherese*: child- or infant-directed speech) is characterized by intonation and prosodic cues, and has been shown to aid segmentation (Thiessen, Hill, & Saffran, 2005). It has been shown that adults are better able to segment artificial languages when given prosodic cues, which seem to serve as a filter on the learned transitional probabilities (Shukla, Nespor, & Mehler, 2007).

Beyond speech segmentation, social cues can reasonably be expected to impact word learning as well. Experiments have found that infants can follow a speaker's gaze to infer what they are referring to (Baldwin, 1993). Episodes of joint attention between an infant and caregiver, as when playing with toys together, show characteristics such as shorter sentences from the caregiver and more utterances from both in the dyad (Tomasello, 1988). Caregivers referring to objects that were already focused on by the infant were correlated with a larger vocabulary, while children of caregivers who attempted to redirect their attention had smaller vocabularies.

Other research seeking to characterize natural interactions between caregivers and children has found that child-directed speech is quite repetitive, with repetitions of phrases, not just single

words (Snow, 1972). An analysis of parent-child interactions while playing with toys showed the informativeness of a variety of social cues relating to the hands and eyes of the speaker, as well as to the continuity of discourse about particular referents (Frank, Tenenbaum, & Fernald, 2013). No single cue served as a perfect filter for the cross-situational learning of words, but in combination these cues much reduce the ambiguity of intended meanings. Hearing an utterance, infants may jointly consider the uncertainty about a speaker's intended meaning as well as uncertainty about the meaning of each word. This framing of the problem as one of communicative inference is the basis for a model that simultaneously learns intended word-referent mappings as well as the relative value of social cues in making such inferences (Johnson, Demuth, & Frank, 2012).

Early robotic models of language acquisition (Steels & Kaplan, 2000) compared the quality of learning input (level of ambiguity between utterances and perceived scene) provided to a robot learner in situations where 1. the human is socially and physical engaged in the interaction, synchronizing pointing gestures towards referents while monitoring the gaze of the robot to ensure gestures and referents are attended to at the right moments; 2. the human is semi-engaged, only using utterances but not using actions to drive the learner's attention; and 3. the human is not socially and physically engaged, only describing the scene with utterances, independently of what the robot is currently looking at. This kind of model allows us to quantify the additional learning efficiency resulting from these various levels of engagement, leveraging embodiment and situatedness. Other projects specifically designed robot learners capable of moving not only to act upon objects but to communicate with social peers and realize joint attention (Scassellati, 1999). Some recent lines of work have used robotic models of embodied social language learners to also study how humans naturally teach language and how they use social cues to provide feedback, for example using motherese (infant-directed speech) or *motionese* to demonstrate simplified and highly informative learning examples (Vollmer & Schillingmann, 2017).

Developmental robotics models have further studied various links between sensorimotor learning and social language learning. For example, a model based on intrinsically motivated learning for efficient coding via active perception learns to copy goals, rather than the specific motor movement, allowing it to learn simple behaviors such as gaze-following (Triesch, 2013). The model begins by observing a tutor's behavior and models the sensory consequences of the behavior. Next, the model acts and receives a reinforcement signal from within that encodes how well its sensations are matched by the sensory model. The model's behavior is adapted to make the sensory consequences of its actions better match the sensory model learned from watching the tutor's actions.

Cederborg and Oudeyer (2013) introduced a model for learning to acquire multiple skills by observing a tutor's ambiguous demonstrations. The model integrates concepts and techniques from earlier cross-situational learning models, as well as models of motor learning by demonstrations that treat meanings as complex sensorimotor policies with coordinate systems that must be inferred. A contribution of Cederborg and Oudeyer is that the model learns both linguistic and non-linguistic skills in a single process, without specifying a linguistic channel to the model. The proof-of-concept demonstrates the viability of this approach, and future investigations will be needed to determine how well it scales, and how well it matches human developmental trajectories.

## *Multimodal regularities*

Other models have studied subtler, but equally fundamental, roles of embodiment. In addition to a flow of passively perceived utterances and visual scenes, embodiment and situatedness provide the learner with the opportunity to also observe concurrently a flow of actions and

effects on the scene (including proprioception). This additional flow of information, enabled by embodiment and consisting in an action-oriented modality, contains structure which can often facilitate statistical inference of ambiguous structures and associations in the linguistic domain (Rohlfing et al., 2006). For example, Mangin et al. (2015) show how invariants (e.g., words) in low-level unsegmented speech streams, as well as their combinatorial structure and associations with objects and actions, can be learned jointly with invariants and structure in low-level flows of images and action movements using multimodal cross-situational learning methods. Like in other related models (e.g., Cangelosi et al., 2016; Sugita & Tani, 2005; Mohammad et al., 2009), such correlated flows of linguistic and sensorimotor information enable inference of general structures of sentences and generalization, i.e., understanding the meaning of new sentences whose precise word sequence was not encountered during training. Another example of the facilitating role of sensorimotor information flows in language learning is the embodied model of linguistic number counting presented in De La Cruz and colleagues (2014). Here, a neural network model is used to account for how children might learn to count linguistically by pronouncing the numbers in sequence, and how this might bootstrap internal representations of numbers that link the names of numbers to meaningful underlying number representations. The model compares a situation where the neural network is only observing sequences of linguistic names, and a situation where the network is also concurrently observing the proprioceptive information of finger counting actions: experiments have shown that observing proprioceptive finger information improves both the accuracy of counting and the quality of the acquired internal representations of numbers. Interestingly, the mediating effect of sensorimotor representations for language learning has also been used to model surprising effects of posture during word-learning experiments (Morse et al., 2015), reproducing the observations of Samuelson et al. (2011) that the inference of word meanings referring to objects can be significantly influenced by the posture children have when they hear these novel words.

## Curiosity, intrinsic motivation, and active learning in language development

Learning in general, and language learning in particular, is not simply a passive information-processing cognitive phenomenon in children. It is also a motivated and active process of inquiry into the external world. Indeed, to learn speech and language, children spontaneously explore how their vocal tract can produce a variety of sounds, and how these sounds produce social effects in their peers, and they systematically point to objects or ask questions about all kinds of things to get linguistic information. Doing so, they collect the large databases of learning examples that are needed to learn language (Oudeyer & Smith, 2016), but this is very costly in brain time and energy: exploration, trial and error, and conversations take a lot of time; and processing the initially unknown linguistic data requires significant cognitive effort. This is particularly mysterious in early speech development, when infants have not yet understood what language is, or how it can be used as a tool to fulfill external goals (e.g., asking a caretaker to bring an object). Nonetheless, infants systematically spend a lot of energy exploring what sounds they can make with their vocal tract (Oller, 2000), not knowing that it may be useful for the yet-to-be-discovered language tool. So one fundamental question is: why do they spend so much energy exploring and learning language? What are the proximal mechanisms that push them to be interested in language learning at the developmental level? Several theoretical perspectives can be taken (Oudeyer, 2006). One consists of speculating that evolution might have selected language-specific motivational circuits that push infants to explore language. However, no precise naturalized formulation of this approach has been articulated so far, in particular in terms of

how these language-specific motivational circuits might be developmentally implemented and how they can address the variety of exploratory language activities. Another perspective is that of social learning, and imitation in particular. While imitation learning indeed plays a major role in language learning (Bloom, Hood, & Lightbown, 1974; Kuhl, 2000), and has been the focus of several computational models (Cederborg & Oudeyer, 2013), it cannot easily account for the full range of spontaneous language exploration shown by infants: adult speakers do not themselves show such systematic exploration (e.g., they do not spontaneously babble all kinds of sounds), and thus imitating the motivated exploration process is not a possibility. Also, while adults provide feedback and encouragement, the general difficulty of using this mechanism to drive the interest of children towards various kinds of activities is not fully compatible with the universal and systematic spontaneous interest shown by children in language exploration.

### *Early language acquisition driven by curiosity*

Another hypothesis is that children are equipped with general intrinsic motivation systems that push them to explore their body, their actions, and their vocal tract and language, through curiosity-driven learning (Oudeyer & Kaplan, 2006; see also Chapter 6, this volume). This hypothesis has been fleshed out in the past decade through a series of computational models of curiosity-driven learning in developmental robotics (Oudeyer & Kaplan, 2006; Oudeyer & Smith, 2016; Forestier & Oudeyer, 2017). Considering child development in general, psychologists proposed early on that humans and other animals may be equipped with neural intrinsic motivation circuits that push them to explore activities and stimuli for their own sake (Berlyne, 1960), as opposed to maximizing an external reward such as food or social feedback. These motivational neural circuits were proposed to rely on intrinsic rewards measuring the interestingness of stimuli or activities in terms of quantities such as novelty, surprise, cognitive dissonance, or intermediate complexity (Berlyne, 1960; White, 1959; Festinger, 1957). Within the past decade, research on computational modeling of these processes of spontaneous exploration driven by forms of curiosity has provided several formal frameworks used to understand these mechanisms (Gottlieb et al., 2013; Friston et al., 2017; Oudeyer, 2018b), and to experiment with in robotic models of sensorimotor learning (Baldassarre & Mirolli, 2013). Within this line of research, some models have considered the hypothesis that intrinsic rewards in humans are provided by sensorimotor activities which provide progress in learning predictive models of the world (Kaplan & Oudeyer, 2007), and have showed how it could enable robot learners to spontaneously discover skills of increasing complexity (Oudeyer et al., 2007; Oudeyer & Smith, 2016). In the Playground Experiment (Oudeyer & Kaplan, 2006), the sensorimotor space included both leg/head movements and (simulated) vocal tract movements, as well as perception of object movements, visual saliency, and sounds. The environment contained both physical objects with affordances and also an "adult" peer robot contingently imitating the vocalization of the learning robot. This experiment showed that the same general curiosity-driven learning system leads the robot learner to engage in orderly exploration and learn how to act upon objects with its legs/head, and how to provoke vocal responses from the peer robot by producing vocalizations, i.e., to enter spontaneously into a primitive form of speech interaction.

Using a similar model, but focusing on the study of the explored vocal sounds, Moulin-Frier et al. (2014) conducted experiments where a robot explored the control of a realistic model of the vocal tract in interaction with vocal peers through a drive to maximize learning progress. This model relied on a physical model of the vocal tract, its motor control, and the auditory system. The experiments showed how such a mechanism can explain the adaptive transition from vocal self-exploration with little influence from the speech environment, to a later stage

where vocal exploration becomes influenced by the vocalizations of peers. Within the initial self-exploration phase, a sequence of vocal production stages self-organizes, and shares properties with infant data (Oller, 2000): the vocal learner first discovers how to control phonation, then vocal variations of unarticulated sounds, and finally articulated proto-syllables. As the vocal learner becomes more proficient at producing complex sounds, the imitating vocalizations of the teacher provide high learning progress, resulting in the well-known infant shift from vocal self-exploration to vocal imitation (Oller, 2000).

### *Discovering the linguistic function of speech utterances*

More recently, Forestier and Oudeyer (2017) extended these models in experiments showing not only how curiosity-driven exploration could lead a learner to explore its vocal tract, but also how it could lead to learning how to use these speech sounds to manipulate simulated social peers, e.g., getting them to bring an interesting object which is out of physical reach. Furthermore, the developmental trajectories generated in these simulations share several qualitative properties with infant development, e.g., overlapping waves phenomena in tool use development (Siegler, 1996), showing the plausibility of the hypothesis that curiosity may play a crucial role in the onset of language development.

### *Active learning generates an ordered curriculum for learning*

Finally, this family of models also enables study of the links between curiosity and the impact of curriculum learning in language acquisition. As reviewed in Smith et al. (2018), the input statistics children are exposed to during their first years evolve with time along a learning curriculum that controls the growth of complexity in the perceived situations. This has been argued to be key in enabling children to learn efficiently and quickly the concepts that are needed for language grounding. The actions and attentional decisions made by infants play a key role in structuring this input, and models of curiosity-driven learning have shown how mechanisms searching for niches of learning progress push the learner to focus on activities or stimuli of gradually increasing complexity (Kaplan & Oudeyer, 2007). In other words, curiosity can be viewed as a mechanism for actively controlling the growth of complexity in language formation (Schueller & Oudeyer, 2016). Indeed, an empirical study of adult learners shows that giving them active control over which objects they will see named in the next trial significantly improves their word-learning performance, as compared to passively viewing a randomly ordered selection (Kachergis et al., 2013). In simulations of learning a full-sized vocabulary with Zipf-distributed word and referent frequency distributions, such self-directed control over the to-be-named referents was necessary in order to make learning possible on a realistic timescale (Hidaka et al., 2017).

## Cultural evolution: how languages become learnable

Not only is language acquired during one's lifetime, but it also evolves over time. Children learn how to walk in more or less the same way today as they did a few centuries ago, but what they learn about the lexicon and the grammar of the same language (e.g., English) is significantly different. Pronunciation may have changed; a lot of new words may have appeared, while some others are not used any more; and grammar structures such as case-marking may have disappeared, for example. This type of evolution happens too fast to be accounted for by biological evolution, with some phenomena even taking place in a matter of weeks (e.g., invention of

new words within a population). Biological evolution has its roots in genetic material being copied and passed on from body to body, whereas cultural evolution takes the form of ideas, words, or conceptual structures being passed on from brain to brain. The cultural evolution of language derives from the repeated interactions between individuals of the population using a language, with everyone learning from and adapting to their interlocutor. These interactions can be between people of the same generation, designated as horizontal transmission, or between different generations, what is called vertical transmission (see Figure 5.2).

## *Cultural evolution can shape languages*

The question is, in the wide landscape of possible configurations and structures, are they all equivalent and only the result of a slow drift of languages? Or, like biological evolution, do some of these structures have an advantage, in particular concerning language acquisition? If we look, for example, at the distribution of vowel systems (De Boer, 2001; Oudeyer, 2018a), word order (Ferrer-i-Cancho, 2016), word frequency (Zipf, 1949), or even lexicon size for the domains of color (Kay, Berlin, Maffi, Merrifield, & Cook, 2009) or kinship (Kemp & Regier, 2012), some structures are far more frequent than others in natural languages, which supports the latter hypothesis. Two main pressures are exerted on language during this evolutionary process: expressivity (how well a language fits the context of its usage) and learnability (how well a language can be transmitted to and acquired by new learners). A third pressure, closely related to the previous ones, is the facility to reproduce the language in terms of both precision and energy needs, highly dependent on the characteristics of the articulo-auditory system of the agents.

## *Language Games and horizontal transmission*

Language Games are a set of computational models in which a population of individuals have pairwise interactions while trying to build or learn a common communication system (Steels, 2001; Loreto, Baronchelli, Mukherjee, Puglisi, & Tria, 2011). For each interaction in a typical Language Game, the corresponding pair of simulated agents – randomly selected from the population – are assigned roles: one is the speaker, uttering a word to refer to a selected meaning or scene, and the other is the hearer, trying to guess what the speaker was referring to. Within a

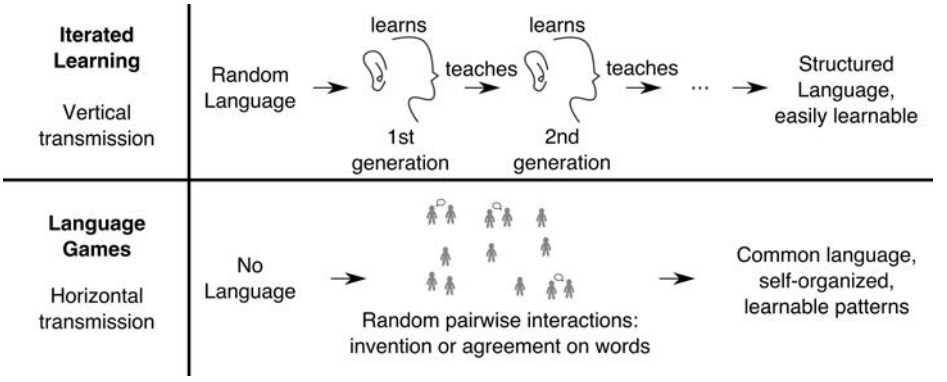



*Figure 5.2* Illustration of the two main classes of computational models of language cultural evolution, and how these processes impact language learnability: Iterated Learning and Language Games.

certain number of interactions, which typically depends on the size of the population, all agents agree on a common language and succeed in communicating efficiently. In other words, while the rules underlying interactions remain simple, a communication system can self-organize. For many of the models, convergence towards a shared vocabulary has been not only observed in simulation but also proven mathematically (De Vylder, 2007; Baronchelli, Felici, Loreto, Caglioti, & Steels, 2006). Moreover, the resulting linguistic structures can show interesting properties, like categories that are well fitted to both the environment and the sensorimotor system of the users. For example, in De Boer (2001) and Oudeyer (2018a), a population of simulated individuals commonly acquire a vowel system. The resulting vowels are always well distributed over the continuous space of possible vowels, and are therefore easily learnable for a new individual that would join the population. Vowels are also selected in a way that minimizes the articulatory energy needed to produce them. A third evolutionary pressure is resistance to noise: because of the non-linearity of the articulatory system, some configurations may be more unstable and sensitive to small variations in the motor commands of the articulatory system. The more stable ones are selected during the evolutionary process. Lending credence to these results, the statistical distribution of the number of vowels over numerous simulations resembles the distribution found in natural languages. Another example is the collective negotiation of names for colors, modeled in different ways (e.g., Steels & Belpaeme, 2005; Puglisi, Baronchelli, & Loreto, 2008). In particular, the model used by Baronchelli, Gong, Puglisi, and Loreto (2010) arrives at a distribution of color categories that is adapted to both the human eye and the frequency of colors in the environment. This model also fits real data, with the average number of color categories produced by the model matching what is observed in the World Color Survey (Kay et al., 2009). Language Games have been used to model many other parts of language, including spatial representation (Spranger, 2012) and grammatical structures (Van Trijp, 2012), and many times the simulated agents are made to interact using real robotic bodies (Spranger, 2012; Steels, 2001).

## *Iterated Learning and vertical transmission*

Another type of model, called Iterated Learning, focuses on language transmission between generations (Kirby, Griffiths, & Smith, 2014). Here, simulated agents also interact in pairs but in chains: each of them represents a generation, and interacts only with the previous generation and the following one. A first random model of language is generated, and a set of examples of usage of this language are shown to the first generation. Not all possible objects are found in the examples: learning individuals have to generalize from a reduced set only. This is an important part of the models, called the *transmission bottleneck*, which leads to modifications of the language in each generation. The first generation later uses what they have learned about the language to generate a new set of examples that is used to teach the language to the second generation. The generalization process relies on built-in cognitive biases of the agents: they tend to prefer compressible languages.

This process is allowed to proceed for a chosen number of generations, and the language of the final generation is observed. The exact definition of Iterated Learning sums it up quite well: "Iterated learning is the process by which a behavior arises in one individual through induction on the basis of observations of behavior in another individual who acquired that behavior in the same way" (Kirby et al., 2014, p. 108). Typically, the objects that individuals have to refer to are combinatorial: they have, for example, a shape and a texture, and all combinations of possible shapes and textures can be found. The final languages range from holistic, with a distinct word for every possible object, to completely structured, with a word for each shape and a word for each texture, the name of the object being a combination of the two. In Kirby, Tamariz, Cornish,

and Smith (2015), it has been shown that with both pressures of expressivity and learnability, structured languages are selected. With only one of the two pressures, languages tend to either be holistic or degenerate (with one single word for everything). Even if the starting language is random, the preferred structure is selected and shaped over generations. This illustrates another mechanism of cultural evolution: some patterns are favored and progressively selected because of cognitive biases, and because of these very biases are easier to acquire by new learners having them as well.

Those models do not pretend to describe the full process of language evolution, as they each focus on some specific aspects of language evolution. Therefore, they do not represent real language evolution as a whole. However, by studying them we understand that simple mechanisms are enough to observe formation and self-organization of languages. Specific patterns and structures emerge and can be selected, which in turn facilitate language acquisition. This provides a theoretical perspective from which one can interpret the relative ease with which children acquire language.

## Conclusion

Modeling the development and learning of language has inspired researchers in computer science, psychology, and robotics to adopt diverse approaches to the many challenges involved. We have sought to highlight the main modeling approaches along with the behaviors and empirical data they seek to explain, while also outlining the remaining gaps between these accounts, where future research must be aimed.

For example, cognitive models of cross-situational word learning carried out in the psychology lab typically assume that words and referents are trivially identified and segmented, and that words always appear with their intended referents – assumptions which are often violated in real-world scenes. While more complex developmental robotics models rarely make these assumptions, both cognitive and robotics models are typically only applied to matching human behavior in small-scale learning scenarios, involving short utterances, a few objects at a time, and a total vocabulary of tens of words. In contrast, other studies use mathematical analysis and simulations of learning a full-sized vocabulary, but often make oversimplifying assumptions about the distribution of words, referents, and even the cross-situational learning mechanism, while only attempting to match gross overall human learning rates. Future studies will need to investigate how well robotics models combine with cognitive models to account for both detailed short-term human learning behavior of vocabulary and also long-term learning in real-world scenes with full-fledged language and grammatical structures.

Another open dimension of research concerns computational modeling of the discovery of speech as a linguistic tool to communicate with others about referents and to achieve joint tasks. Indeed, most existing computational models (there are few exceptions) have so far relied on cognitive architecture models where language is implicitly assumed to be a system of labels associated with communicative referents. However, for early developing infants, speech sounds (like gestures) are initially part of a rich, unorganized, and continuous flow of multimodal information: the special communicative status of these sounds (or gestures) is only progressively discovered. This also highlights the need to develop further computational theories of the ways language development is embedded within the broader picture of sensorimotor, cognitive, and social development.

## Note

1 Some material from this section was adapted from Oudeyer (2018a, CC-BY).

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# 6

# BUILDING THE FOUNDATIONS OF LANGUAGE

## Mechanisms of curiosity-driven learning

*Katherine E. Twomey and Gert Westermann*

### Introduction

The field of language acquisition benefits from a rich experimental literature. The majority of this work employs carefully controlled experimental paradigms designed to isolate and test the effect of a given set of variables on learning, and to rule out the effect of extraneous factors. For example, experimental studies of word learning typically use novel words and control how often a child hears these words so that the researcher can be confident any between-condition differences in behavior are the result of the experimental manipulation and not the number of times children heard the word; similarly, in sentence repetition tasks investigating older children's syntactic development, linguistic variables are controlled to ensure repetition relates to grammatical structure and not to other characteristics of the stimuli such as lexical frequency.

However, in contrast to the constrained lab environment required for good experimental control, the majority of infants' and toddlers' real-world learning takes place in a messy, cluttered learning environment. While a child participating in an experiment typically sees a fixed number of stimuli in a predetermined order, outside the lab children explore their world freely, attending to what they encounter at their own pace, in the context of their learning history, in whatever order they choose. Importantly, then, children play an active role in their own early learning by extracting information from the environment as they choose and consequently imposing a structure on this environment. Put differently, early learning is driven by the child's intrinsic motivation, or curiosity. Critically, curiosity is likely also to be important to language acquisition, since the child is free to attend to linguistic and nonlinguistic stimuli and to extract information from this rich environment. Nevertheless, the role of curiosity in early development has only recently begun to be studied in earnest, and the mechanisms by which curiosity might drive language acquisition are yet to be clearly defined. The current chapter reviews classical psychological theories of curiosity, describes recent work implementing these theories in artificial learning systems and explores current findings from developmental psychology that point towards a link between curiosity, attention and language at the earliest stages of development.

## Theoretical approaches to curiosity

### *Curiosity, motivation and attention*

Historically, curiosity has been closely associated with the notion of *intrinsic motivation*. As adults we spend substantial time engaged in activities such as watching television or listening to music. These behaviors are intrinsically motivated; unlike extrinsically motivated behaviors, where an action is carried out to satisfy some external criterion, intrinsically motivated behaviors have no external goal, but rather are carried out simply for their inherent reward (Berlyne, 1960; Ryan & Deci, 2000). For example, eating is externally motivated by the need to satiate hunger, and the action of memorizing a vocabulary list to pass a language test is externally motivated by the desire to pass the test, while playing a computer game or singing to oneself while taking a shower attracts no external reward. Intrinsically motivated behaviors are also evident early in development. For example, infants begin to babble spontaneously, not driven by an externally mediated reward (Moulin-Frier, Nguyen, & Oudeyer, 2014); similarly, infants who are expert crawlers nonetheless transition to the initially much more effort- and errorful stage of walking (Adolph & Tamis-LeMonda, 2014). In contrast, other early behaviors, for example, tidying toys or helping an adult reach an object out of their reach, have clearly identifiable extrinsic motivations (e.g., eliciting praise). More broadly, however, behaviors often have both intrinsic and extrinsic motivations; for example, someone riding a bicycle both because it is enjoyable and because they want to improve their health.

Curiosity is typically viewed as a form of intrinsically motivated behavior in which a learner or agent interacts with the world to gain information without seeking an externally mediated reward. Curiosity-driven behaviors therefore mediate between what the learner already knows and what is to be learned; that is, curiosity can determine what information is sought and when by determining how the child allocates his or her attention. The puzzle of curiosity, and the focus of work across philosophy, psychology and computer science, is therefore to understand the intrinsic motivation mechanisms which underlie curiosity, and to explain how the resulting curiosity-driven behavior is shaped by – and indeed shapes – factors both intrinsic and extrinsic to the child.

Due to the complex nature of curiosity, many theories of the cognitive basis of curiosity have been proposed, until recently largely from the perspective of curiosity in adults. Below, we review three principal curiosity mechanisms which have been the focus of substantial theoretical and experimental work (but note many other implementations are possible; for a comprehensive review, see Oudeyer & Kaplan, 2009). All three can be broadly described as a drive to accumulate information; however, the precise processes by which information is acquired vary, with a range of implications for curiosity-driven learning in early development.

### *Incongruity approaches*

On *incongruity* approaches, curiosity relates to the disparity between what a learner knows and the perceptual input they receive: when the incongruity is large, the learner attends to a stimulus in order to address this gap (Berlyne, 1960; Hebb, 1949; Piaget, 2013). Thus the key cognitive mechanism in incongruity approaches to curiosity is an intrinsic motivation to reduce the disparity between the external world and the learner's internal representations. Indeed, there is evidence that human and non-human learners spontaneously orient their attention to new

information. Sokolov (1963) extended early work by Pavlov to identify an *orienting reflex* in both behavioral and neural responses to novel stimuli, by which attention increases to new information, but gradually decreases across time as this information is assimilated. In the context of incongruity approaches, then, the orienting reflex represents a mechanism for reduction of disparity between the environment and representation. Once the stimulus has been learned as fully as possible, the learner has *habituated*, at which point attention is reoriented to a more novel stimulus. Incongruity approaches relate closely to infancy research, in which researchers frequently capitalize on this orienting reflex in looking time studies, and in particular in familiarization paradigms (e.g., Althaus & Westermann, 2016; Plunkett, Hu, & Cohen, 2008), which have demonstrated that even early in development, language can affect how infants distribute their attention (for more discussion of the orienting reflex in infancy, see below).

## *Information gap approaches*

While orienting to novelty may explain at least some exploratory behavior in very early learning, across development, rigidly adhering to such a strategy could lead to less-than-optimal outcomes. For example, while falling off a cliff is certainly novel, few learners attempt to experience it for themselves, let alone repeatedly. *Information gap* approaches involve the learner perceiving that there is missing information in their mental representation of a particular situation, and seeking to fill this gap (e.g., Festinger, 1962; Kagan, 1972; Loewenstein, 1994). For example, a driver waiting at a road junction will seek information from traffic lights to establish whether it is safe to proceed. Information gap approaches are therefore similar to incongruity approaches in that, in both, curiosity involves reducing a gap in knowledge about the world. Critically, however, incongruity theories require that learners consciously notice this gap; by extension, these approaches necessarily assume that infants can reflect on their existing knowledge in order to identify the gap which needs to be addressed in order to achieve that goal (Gottlieb, Oudeyer, Lopes, & Baranes, 2013). Thus, it is not clear that such approaches can account for early curiosity-driven attention before the development of the higher-level metacognitive processes that allow learners to reflect on what they know.

## *Learning progress approaches*

More recent theories of curiosity assume that curiosity is an intrinsic motivation to maximize learning (or competence) progress (e.g., Little & Sommer, 2013; Oudeyer, Gottlieb, & Lopes, 2016; Oudeyer & Smith, 2016; Schmidhuber, 2010). Broadly, like incongruity and information gap approaches, learning progress theories involve the reduction of disparity between internal representation and environment; however, a key difference is that learning progress accounts hinge on the reduction of prediction error. Specifically, the learner makes predictions about the environment (or the outcome of an action), and compares this prediction to the true state of the world (or true action outcome). In addition to prediction error-based learning, these approaches invoke an additional cognitive component: curiosity as an intrinsic motivation to maximize learning progress. Curiosity-driven exploration therefore emerges from the motivation to seek out new situations which offer the greatest possibility for maximizing learning (i.e., reducing prediction error). These contemporary formalizations of the potential mechanisms underlying curiosity have been implemented in a range of computational robotic models of curiosity-driven learning, one of which is discussed in detail below, and show promise in capturing developmental phenomena (e.g., Forestier & Oudeyer, 2017).

### *Evaluating competing theories*

It is important to note that there is at present no consensus as to what cognitive computations learners perform when engaging in curiosity-driven behavior, and even the behaviors themselves are notoriously difficult to define. This point is exemplified by Berlyne's (1960) seminal early work, in which he proposed that curiosity-based actions vary along two orthogonal dimensions: perceptual/epistemic and specific/diversive (for a detailed review, see Loewenstein, 1994). Thus, any curiosity-driven behavior can be located anywhere along conjoint perceptual/epistemic and specific/diversive continua.

The perceptual/epistemic continuum relates to the extent to which a behavior is the result of concrete perception or more abstract knowledge: perceptual curiosity relates to attraction to novelty, while epistemic curiosity is a drive to acquire knowledge. The specific-diversive continuum relates to whether or not the learner aims to gain a particular piece of information: specific curiosity is a drive to acquire a specific piece of knowledge, while diversive curiosity is a desire to increase the general information content of the current situation. Thus, according to Berlyne, any non-extrinsically motivated behavior will fall somewhere along these continua. For example, the child attempting to discover how to open a toybox to obtain the contents would be acting on specific-epistemic curiosity, while an infant reorienting its attention after habituation would be engaging in perceptual-diversive curiosity. From this perspective, all three mechanisms reviewed above could play a role in shaping children's attention during learning. More broadly, Berlyne's work highlights the challenge in pinpointing *how* curiosity works, when there is no agreement as to *what* curiosity looks like (Kidd & Hayden, 2015).

## Computational curiosity

Despite this lack of consensus, substantial progress in understanding the mechanisms underlying curiosity has been made in the field of computational modeling, and at present, the majority of work across disciplines to focus specifically on curiosity-driven learning comes from the field of computational reinforcement learning. In this work, researchers implement psychologically inspired exploration-based learning mechanisms in artificial computational and/or robotic learners, with the goal of building a system that can learn autonomously and optimally. These systems are inspired by work in human reinforcement learning, which has demonstrated that the neurotransmitter dopamine reinforces learning following rewarding events. The precise role of dopamine in learning is complex and the focus of active research (for a review, see Bromberg-Martin, Matsumoto, & Hikosaka, 2010). Broadly, however, dopamine-releasing neurons are understood to increase their production of the neurotransmitter in response to external environmental input that is better than predicted, reinforcing the successful action or response such that it is more likely to be produced in future. For example, dopamine release is increased in response to discovery of food or water (Schultz, 1998). Computational reinforcement learning approaches are based on this mechanism, employing an artificial reward system by which the system receives a numerical reinforcing signal when it carries out an action or encounters an environment that leads to a particular outcome (for a detailed discussion of the relationship between biological and computational reinforcement learning, see Kaplan & Oudeyer, 2007). The larger the reward, the more likely the learner is to repeat the action or seek out the circumstances that elicited it. Curiosity is therefore a mechanism for driving exploration such that reward is maximized. Consequently, a central question in this field is how to specify how this reward is calculated, that is, to develop a mechanism for curiosity (Oudeyer & Kaplan, 2007).

In fact, computational models employ a range of different implementations of curiosity, reflecting the range of existing theories. In line with information gap approaches, computational curiosity has been modeled as prediction error reduction. For example, Schlesinger and Amso (2013) presented an intrinsically motivated artificial learner with five sets of potential visual exploratory sequences of a series of naturalistic images. Each set of sequences consisted of samples of gaze data over an image. One set of samples was generated by 9-month-old infants and one by adults, with the remaining three generated artificially based on attributes of the images (salient areas, noisy areas or random sampling). For each set, samples were presented one-by-one to a simple recurrent neural network (Elman, 1990) that learned across training to predict which sample should appear next in the sequence, resulting in five networks trained on infant, adult or image-based sequences. For each network, error across learning was recorded, reflecting the accuracy with which the network had learned the sequences. The artificial learner then selected a network to learn from. Next, the artificial learner received a reward that was proportional to that network's error. Importantly, in the types of neural network employed in this study, error reflects the ease with which the network can encode its inputs: stimuli that are easy to learn result in low network error, while stimuli that are difficult to learn result in high error. Thus, because the artificial leaner received greater reward for choosing low error networks, and would therefore learn to choose low error networks in future, over time the learner would choose networks which had been trained with easy-to-learn sequences. Critically, the artificial learner systematically preferred the network that had learned to predict the exploratory sequences generated by infants, suggesting that infants' image scanning generated sequences of gaze samples that were easier to learn than either artificially or randomly generated sequences. As a consequence, this simulation suggests that infants can spontaneously minimize prediction error. This reinforcement learning-based simulation indicates that prediction error reduction is a potential mechanism for curiosity-based learning and predicts that infants are capable of generating exploratory sequences that maximize their own learning when allowed to engage in curiosity-driven visual exploration.

However, models that rely only on minimizing prediction error to generate reward cannot account for the diversity of infants' exploration in complex learning environments. To address this issue, Oudeyer, Kaplan, and Hafner (2007) modeled curiosity as a motivation to maximize learning progress. In this "playground experiment", two dog-like robots are placed on a play mat surrounded by toy objects. One robot is the "learner", and the other is the "teacher". Each can vocalize; the learner spontaneously produces vocalizations when looking at the teacher, while the teacher imitates the learner's vocalizations. Both robots possess a series of primitive motor functions that allow them to explore the objects by grasping them with their mouths or pushing them with their limbs. The learner robot attempts to predict the outcomes of its actions on the toys, and receives a reward based on the extent to which its predictions are improved or worsened based on a given movement (i.e., reducing prediction error). Thus, successfully predicted actions are more likely to be repeated than unsuccessfully predicted actions, leading to learning progress, in turn leading to a reward. However, once a particular action is well learned (with reduced opportunity for learning progress), the robot explores new possibilities for action. By initially randomly exploring the environment and receiving a reward for successful predictions, then, the learner robot fine-tunes its exploration across experience and learns to explore action spaces that allow it to learn most rapidly, without being explicitly told how best to learn.

Particularly relevant to the current discussion, one action space available to the robot is vocalization. Specifically, when the learner robot vocalizes, the teacher robot is preprogrammed to respond. Based on its intrinsic motivation to maximize global learning progress while minimizing error in predicting the outcome of a particular action (here, vocalization), the learner

robot exhibits turn taking in vocalizations with the teacher, suggesting that curiosity may play a role in the development of early vocal interaction (Oudeyer & Smith, 2016). Importantly, this model is one of the first to address the link between curiosity and the beginnings of language, by treating vocal behavior as part of the same learning progress maximization system as intrinsically motivated exploration (but see also Forestier & Oudeyer, 2017).

These models are just two examples of the many computational investigations of curiosity from the reinforcement learning field. Other models have also been shown to autonomously maximize their own learning, using a range of implementations of curiosity (for reviews, see Gottlieb et al., 2013; Oudeyer et al., 2007). Thus, currently there is no single optimum mechanism for calculating reward in curiosity-based learning. However, since the goal of this type of model is to build an artificial agent that can learn independently, many models, while inspired by work in psychology, include elements that need not reflect early developmental mechanisms (Oudeyer & Kaplan, 2009). For instance, both the models reviewed include a metacognitive module that can "reflect" on what has been learned and decide to select a particular course of action. However, precisely when metacognition emerges in children is currently unclear (Schneider, 2008). Overall, however, this work in computational reinforcement learning signposts critical new directions for empirical work towards understanding the mechanisms driving early development – and consequently early language acquisition (Gottlieb et al., 2013).

One recent model aimed to simulate curiosity-driven learning in infancy without invoking metacognition. Twomey and Westermann (2017) described a simple neural network model that selected the order in which it learned from stimuli in a category learning task. The authors used an autoencoder architecture (e.g., Mareschal & French, 2000), which learns over repeated encounters with a set of inputs to represent what it sees. Autoencoders do not require a separate "teacher" during learning, and are not dependent on an engineered reward module, and are therefore a useful tool for simulating early developmental processes. Existing work with these networks has captured empirical results in infants' category learning using a simulated familiarization/novelty preference task in line with the canonical empirical method of examining infants' category learning (French, Mareschal, Mermillod, & Quinn, 2004; Westermann & Mareschal, 2012, 2014). In these tasks, infants learn from a series of images presented in a fixed order (e.g., Mather & Plunkett, 2011; Quinn, Eimas, & Rosenkrantz, 1993; Younger & Cohen, 1983). In contrast, this model was allowed to select the order in which it viewed stimuli based on a novel implementation of curiosity. Curiosity was modeled broadly as an intrinsic motivation to maximize learning at each learning step, but specifically as a function of what the model had learned already, combined with in-the-moment information from the environment and the model's ability to learn from that particular stimulus. By choosing the stimulus that maximized this curiosity function, the model learned optimally relative to an identical model trained with fixed stimulus presentation, and did so by selecting stimuli in a sequence of intermediate complexity. Like the models reviewed, this work indicates that infants' learning in the real world should show systematic patterns of exploration, but offers a mechanism that does not depend on cognitive capacities that develop post-infancy. However, this work leaves open the important question of how language and curiosity-driven learning are related.

## Curiosity in early development

Given its fundamental role in learning, to date surprisingly little empirical work has focused on curiosity in infants. Observationally, however, infants show clear curiosity-type behaviors: during play they chew and bash toys, shake and roll them, even throw them – actions which are not motivated by any external reward. Revisiting the existing literature also provides evidence

for the prevalence of curiosity-driven behavior in infancy and early development. For example, in line with incongruity approaches in which curiosity is a drive to minimize the discrepancy between the external world and the learner's internal representations, given experience over time with a particular stimulus infants will switch their attention when a novel stimulus appears (Fantz, 1964), a much-replicated phenomenon known as the *novelty preference* (see orienting reflex, above). This phenomenon suggests that some kind of prediction error reduction mechanism may be at play in early infancy: infants orient to stimuli that do not conform to their predictions, and continue to encode them until their predictions are correct. Further evidence comes from early work which shows that greater stimulus complexity engages infants' attention; for example, by 6 months infants have been shown to look for longer at black and white checkerboard stimuli consisting of many small squares than stimuli consisting of fewer, larger squares when the overall ratio of black to white was controlled (Fantz & Fagan, 1975; see also, e.g., Cohen, DeLoache, & Rissman, 1975; Colombo, Frick, & Gorman, 1997; Tellinghuisen & Oakes, 1997). Thus, some of the determinants of curiosity-driven attention theorized to be operating in adults – and, in particular, attention to novelty – are also seen early in development.

However, establishing a clear link between novelty in the environment and infant curiosity is not trivial. With respect to the novelty preference, the picture is more complex than a simple increase in attention to the most novel stimulus present: under some circumstances infants prefer familiar stimuli, and the extent to which they orient their attention towards familiarity or novelty in looking time studies can be manipulated experimentally by varying stimulus presentation times (Balas & Oakes, 2015; Houston-Price & Nakai, 2004; Mather, 2013). Specifically, in these studies infants show a familiarity preference after shorter exposures but a novelty preference after longer exposures. Further, as Berlyne (1960) points out, novelty can be complete (a never-before-seen toy), long-term (a toy not seen today, but played with yesterday) or short-term (a toy played with in the past few minutes). Novelty can also be absolute, as in the never-before-seen objects commonly used in studies of word learning, or relative, as in the out-of-category "novel" stimuli often presented in studies of infant categorization. More broadly, patterns of curiosity-driven exploration are not easy to predict: infants' attention allocation and exploratory behaviors emerge from the interaction between the infant, the infant's particular learning history, and in-the-moment features of the task environment. For example, while one infant may be familiar with their favorite 3D dinosaur toy, another may have only seen dinosaurs in picture books. When encountering a new toy dinosaur at nursery, each child's exploration of the object will depend not only on the features or affordances of the object itself, but also on the child's previous experience. Thus, while novelty is an important determinant of curiosity-driven attention, novelty itself is subjective; curiosity-driven behavior therefore depends fundamentally on the dynamic interaction between external, perceptual input and the child's learned representations (Kagan, 2009; Oudeyer et al., 2016; Twomey & Westermann, 2017). Understanding this interaction is a current challenge for developmental psychology.

The recent studies of curiosity in development employ a range of paradigms but offer converging evidence that infants and children are active learners who systematically sample their learning environments; moreover, these early empirical studies indicate that curiosity-driven learning involves imposing structure or regularity on the input to learning. This ability appears to start very young. For example, Kidd and colleagues (Kidd, Piantadosi, & Aslin, 2012) used a looking time paradigm to explore infants' preference for learning from stimuli of different levels of complexity. Specifically, they presented 7- to 8-month-old infants with a series of videos of occlusion events, in which a brightly colored occluder disappeared to reveal either an image of an object such as a fire truck, or a blank screen. The probability of an object appearing varied from 0 to 1; thus, while some objects appeared on every trial, some objects did not.

Consequently, some trial types were highly predictable (or simpler), while others were highly unpredictable (or complex). The authors found a "Goldilocks effect": infants preferred to look at trials which were moderately predictable, but not highly predictable or unpredictable (for a similar finding in auditory attention, see Kidd, Piantadosi, & Aslin, 2014; see also Yu, Bonawitz, & Shafto, 2017).

This preference for intermediate complexity has been replicated in a category exploration task in which complexity was indexed by perceptual distances between stimuli. Twomey, Malem, and Westermann (2016) presented 12-month-old children and adults with a shape priming task to explore what level of complexity infants generate when engaged in curiosity-driven category exploration. In a 2D eye-tracking paradigm infants saw abstract shapes presented on a computer screen. Shapes were drawn from a novel category of five exemplars which varied along a continuum in which the differences between successive exemplars were controlled; specifically, exemplars varied systematically along a shape continuum (wide to narrow) and a color continuum (red to blue). Each step along the continuum was taken as a perceptual distance of 1; thus, infants could traverse short distances (i.e., 1), medium distances (i.e., 2) or long distances (i.e., 3). On prime trials, infants saw one of the two category-peripheral exemplars; on test trials, they saw the remaining four exemplars, and were free to scan these for 10 seconds. For each sequence generated in the 10-second free exploration phase, the mean of the perceptual distances was calculated and served as a proxy for sequence complexity. In line with Kidd and colleagues' (2012) findings, infants' visual exploration was systematic: their first looks were consistently to stimuli of intermediate distance from the prime. Analyses of individual differences in scan sequences also indicated that infants spontaneously imposed structure on their input: following their first look, some (although not all) infants systematically generated sequences of intermediate difficulty. As well as extending Kidd and colleagues' findings to a different measure of task "complexity" (i.e., perceptual distance versus predictability), this work provides evidence convergent with computational work (Schlesinger & Amso, 2013; Twomey & Westermann, 2017) that infants are not passive learners or simply random explorers: rather, in visual exploration at least, infants appear to prefer to learn from stimuli of intermediate complexity and, importantly, systematically select information in order to generate this level of complexity. Importantly, prior to these studies it was not clear what level of environmental complexity would best support early learning. For example, in experiments in which what infants see is more constrained, newborns have been shown to learn best from simple sequences (Bulf, Johnson, & Valenza, 2011), while maximizing complexity can support 10-month-old infants' category learning (Mather & Plunkett, 2011). This newly emerging research suggests that in contrast, when allowed to explore freely, infants prefer to learn from intermediate complexity.

While curiosity in early development is the focus of ongoing research, these findings have interesting links with classic theories of learning. In particular, in Vygotsky's (1978) influential work in educational theory, children's *zone of proximal development* (ZPD; the amount – and therefore maximum – they can develop at a given time) is defined by a more capable tutor structuring their input such that it is sufficiently challenging for them to learn, but not so challenging that learning is impossible. That is, the ZPD represents a learning space of intermediate difficulty. These early studies of infants' curiosity-driven learning raise the possibility that while input from social partners is clearly important, infants themselves are capable of defining their own ZPD.

## Curiosity and language

As noted, the relationship between curiosity, attention and early language development has only recently been explicitly studied, and much of this work is ongoing. However, findings from

traditional experimental paradigms suggest that hearing language during learning can affect how children allocate their attention. Months before the onset of speech, infants as young as 6 months have been shown to direct their attention to the correct referent when they hear a familiar word (Bergelson & Swingley, 2012). Novel words also affect attention: 10-month-old infants hearing words during category learning demonstrate increased attention to category-relevant features of stimuli (Althaus & Mareschal, 2014), and the presence of language shapes the category representations they ultimately learn (Althaus & Westermann, 2016; Plunkett, Hu, & Cohen, 2008). In toddlers, the presence of novel words during a match-to-sample task increases the duration of infants' fixations while scanning potential referents (Carvalho, Vales, Fausey, & Smith, 2018) and increases the amount of time spent engaging with 3D objects (Baldwin & Markman, 1989). Interestingly, language need not be present in-the-moment: knowing an item's name prompts infants to increase their attention to that item even when that item is presented in silence (Gliga, Volein, & Csibra, 2010; Mani & Plunkett, 2010; Twomey & Westermann, 2018).

Importantly, while these studies suggest that language affects children's attention and consequently the nature of the input to learning, recent work suggests that nonlinguistic aspects of the learning environment also have profound effects on language learning. For example, the presence of variability in the visual scene can facilitate noun acquisition and longer-term vocabulary development (Goldenberg & Sandhofer, 2013; Perry, Samuelson, Malloy, & Schiffer, 2010; Twomey, Ma, & Westermann, 2017), while visual characteristics of a potential referent determine how children generalize words (e.g., S. S. Jones, Smith, & Landau, 1991; Landau, Smith, & Jones, 1988; Son, Smith, & Goldstone, 2008). Overall, a picture is emerging of a dynamic interaction between linguistic and nonlinguistic input in early language acquisition. This point is critical: evidence is building that infants can actively select information in their learning environment to generate their own input to learning. Given that the nonlinguistic input affects early language acquisition, curiosity-driven learning may have a profound effect on language acquisition. Understanding curiosity in development is therefore fundamental to our understanding of language development. Current work on learning outside the constrained lab environment, inspired jointly by computational work and recent empirical studies, is under way to generate critical insight into this complex relationship.

## Implications

As is clear from this review, current theories of curiosity are heterogeneous. Such is the complexity of the problem, in fact, that Kidd and Hayden (2015) recently argued that researchers in developmental psychology at least for now should put to one side theoretical debates and move towards characterizing and understanding the behavior in order to ensure progress continues to be made. At present, then, there remains much work to be done in understanding how young children can drive and even maximize their own learning and in particular how this ability interacts with language. Nonetheless, research has begun to highlight important avenues for future research with important implications for the development of interventions in atypical (language) development.

First, an important message from the current work is that infants can drive their own learning, and that this exploration depends critically on what the infants already know. Taken to its logical conclusion, then, the emerging picture of curiosity-driven learning highlights the importance of play-based learning to early development and raises the possibility that early years education should emphasize exploration-based learning over instruction with pre-prepared materials. Indeed, recent work in related educational settings indicates that eliciting curiosity may prove a useful pedagogical tool: for example, school age children have been shown to better retain

facts that elicit greater curiosity (Walin, Grady, & Xu, 2016), and work in robotics highlights the benefit to learning of curiosity on the part of the instructor (e.g., Gordon, Breazeal, & Engel, 2015). Investigating the role of curiosity in the early years educational context, and in particular in early language acquisition, is an important avenue for future work.

Second, the infants who took part in existing studies of curiosity were typically developing. It is possible, therefore, that in atypical development the structure (input) infants generate is different from that generated by typically developing children, and this, in addition to identified neurocognitive impairments, may in part explain delays in learning. For example, in the case of autism spectrum disorder (ASD), infants at risk for autism who go on to develop socio-communicative difficulties show different patterns of attention allocation to low-risk controls (Bedford et al., 2012; for a review, see Jones, Gliga, Bedford, Charman, & Johnson, 2014). Clearly, characterizing curiosity-driven exploration in typical development is critical for developing tools to identify atypical exploratory styles. In terms of intervention, such a characterization could also provide insight into the features of the learning environment that best support learning, and the foundation for designing interventions that make these features more readily accessible to atypically developing children.

Third, and importantly, while this work emphasizes infants' impressive ability to learn independently, clearly not all learning takes place in isolation: substantial amounts of curiosity-based learning take place during social interactions, particularly as language develops. Thus, understanding how the child's intrinsic curiosity interacts with and may be shaped by input from caregivers is an important avenue for future research.

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# 7

# VISUAL OBJECTS AS THEY ARE ENCOUNTERED BY YOUNG LANGUAGE LEARNERS

*Hanako Yoshida and Caitlin M. Fausey*

How do infants and toddlers learn to talk about objects? We know that concrete visual objects like CUP, BALL, and SPOON are among the first-named objects (Caselli et al., 1995; Gentner & Boroditsky, 2001). We know a lot about how what young learners *hear* shapes what they say (Goodman, Dale, & Li, 2008; Snow & Ferguson, 1977; Weisleder & Fernald, 2013). Research on the early stages of language learning has focused on language input and how infants find words within a speech stream ( Jusczyk & Aslin, 1995; Saffran, Aslin, & Newport, 1996). However, we know very little about how what children *see* matters for their language achievements. In this chapter, we first review key points regarding visual learning that are relevant to early language learning, including how children segment and attend to visual objects. We then review evidence about children's egocentric views of objects and their relevance for language learning. We conclude the chapter by discussing two new directions – the role of language in creating visual experiences and atypical language development – for language learning research grounded in these recent discoveries about visual objects as they are encountered by young language learners.

## Finding visual objects

For infants to learn about objects and their properties, to form memories of those objects, and ultimately to learn the names of objects and their categories, infants must first find the objects in potentially complex and cluttered scenes in which objects overlap and may be partially occluded. Developmental research in vision science has provided programmatic and elegant experiments showing that the ability to segment a partially occluded object and represent it as a unified entity starts developing early (Valenza & Bulf, 2011), but progresses gradually during the period from birth to 6 months (Johnson & Aslin, 1996). This process is highly dependent on object motion that is independent of background (Johnson & Aslin, 1995; Kellman, Gleitman, & Spelke, 1987; Slater, Morison, Somers, Mattock, Brown, & Taylor, 1990) and is related to infants' experiences and practice in tracking objects (Busking, Botha, & Post, 2010; Johnson, Davidow, Hall-Haro, & Frank, 2008; Valenza & Bulf, 2011). Experiments studying early segmentation have typically presented infants with single planar views of an object with lateral or looming motions, both of which support segmentation (Busking et al., 2010; Johnson et al., 2008; Valenza & Bulf, 2011; cf. Graf, 2006; Hummel & Biederman, 1992). This is particularly interesting, because recent observations of how parents show objects to young infants suggest that parents show objects so

that the child sees a lot of the objects' flat surfaces but rarely any depth or angles. Parents show objects with shaking, looming, and lateral movements or planar rotations (Matatyaho & Gogate, 2008; Thelen & Smith, 1998). These are observed in parent-infant interaction, specifically in the moments when parents hold and move objects during word teaching contexts and/or play. Critical visual experiences such as the feature-rich single viewing of objects could be in part supported by these social interactions that may both capture attention and segregate the object from the background.

## Attending to visual objects

To learn about an object, infants must also sustain focused attention on the object. Infants successfully learn about an object only when they catch relevant information about it, and this requires rapid and well-controlled attention. One major milestone in attending to objects is when infants can follow moving objects and/or the hand pointing toward objects. Such attentional organization emerges in infants as young as 3 months, helps early learners identify word meanings, and serves potential communicative functions (Ruff & Rothbart, 2001).

Most research examining infant visual attention has measured looking behavior such as habituation or preferential looking tasks (Kellman & Banks, 1998; Reynolds, Courage, & Richards, 2013). Looking duration has also been used to index information processing and/or intelligence (Colombo, 1993; Colombo & Mitchell, 1990; Tamis-LeMonda & Bornstein, 1989) as well as cognitive functioning (Rose, Feldman, & Jankowski, 2012). In these efforts, visual attention is used primarily as an index of discrimination or recognition. For example, one of the most commonly used measures of recognition in infant research presents an infant with a stimulus for a set length of time, followed by comparison trials in which two visual stimuli are presented simultaneously to the left and right of midline. The sensitivity to novelty is the proportion of infant looking toward the novel stimulus out of the total looking time toward both stimuli, and this score serves as an index of learning. If the infant recognizes the familiar stimulus, then she/he would be expected to look longer toward the novel stimulus and demonstrate recognition.

The visual attention skills studied in this literature, aimed at discovering properties of early visual attention and the impact of attention on visual recognition memory (Colombo, 2001; Reynolds et al., 2013), are also highly relevant for tasks designed to measure how young children understand words. The most recent documentations of young infants' understanding of object-word associations have used experimental paradigms that measure infant looking behavior – a task known as "looking while listening" (Bergelson & Swingley, 2012; Fernald, Zangl, Portillo, & Marchman, 2008). In the typical setup, infants are shown two discrete images, one of which is labeled in a spoken sentence ("Do you see the apple?") to examine whether or not infants look toward the named item (correct item), indicative of their knowledge about the relation between the referent and its name. Findings from this literature have demonstrated that orienting attention to referents when hearing words is a critical skill for learning words and becomes more efficient with time and experience (e.g., Bergelson & Swingley, 2012; Weisleder & Fernald, 2013). One outstanding question is: How do everyday learning contexts and viewing experiences shape this changing attentional trajectory? What factors help to organize looking behavior and support linking heard names to seen objects?

## Developmentally gated contexts for learning about objects

Early visual experiences and the development of attention take place in a dynamically changing context that frequently involves other social beings. Social partners' referential cues – gaze,

pointing, touching, object handling, object showing, tapping – strongly influence communication and language learning throughout a wide age range of typically and atypically developing children (Iverson et al., 1999; Landry & Chapieski, 1989; Leekam, Hunnisett, & Moore, 1998; Matatyaho & Gogate, 2008; Yu & Smith, 2016). Parents and caregivers also modify their behavior, based on the skills and interests of their infant, in ways that matter for access to visual objects (Bornstein, Tamis-LeMonda, Hahn, & Haynes, 2008). Specific to object naming, observations of how parents show objects to very young infants suggest that the ways parents hold and dynamically move objects near the baby's face are a potent force for early looking behavior, at least in the multimodal context of naming objects (Gogate, Bolzani, & Betancourt, 2006). In addition, parents change the way they play with their child flexibly to adapt to the child's needs – based on the child's age (Brand, Baldwin, & Ashburn, 2002), developmental achievements like object knowledge (Dimitrova & Moro, 2013), communication skills (Iverson et al., 1999; Doussard-Roosevelt, Joe, Bazhenova, & Porges, 2003; Lemanek, Stone, & Fishel, 1993), and language development (Kasari & Sigman, 1997; Landa, Holman, Garrett-Mayer, 2007; Wray & Norbury, 2018). Parental adaptations influence young children's early visual experiences and attention, and as infant responses – looking, smiling, and vocalizing – become more complex, parents' responses become more complex and coordinated with their infant's responses (Carpenter, Nagell, Tomasello, Butterworth, & Moore, 1998).

These dynamic social exchanges and experiences with object playing can also change dramatically as the infant's physical and motor experiences change. For example, early reaching movements appear to be related to increases in attention to faces and objects in face-to-face play (Libertus & Needham, 2011), in addition to object play per se during early interactions (Striano & Stahl, 2005). Also, the transition from crawling to walking typically develops over a very broad age range, 9 to 14 months, and with this transition there are many concurrent social changes: crawlers cannot easily carry objects and are less likely to share and show objects, and parents are less likely to respond to their bids for attention with an object; walkers can easily carry objects to parents, they show objects more, they make more bids for attention – even from a distance – and parents are more responsive to these bids (Campos & Bertenthal, 1990; Karasik, Tamis-LeMonda, & Adolph, 2011). These changing joint interactions with objects create unique visual opportunities for the young learner; the objects in the visual input over the course of these interactions are the data available to young learners as they are learning to connect objects and their names.

The value to developmental researchers of direct access to what visual information is available to the child, and how it changes over time, is considerable in a wide range of fields, including the study of perceptual development, motor control, social development, and language learning. There is an increasing interest in understanding the origins of object name learning by measuring the dynamic first person view in natural contexts and activities. Researchers have now solved a number of technical challenges that had previously impeded progress, including recording devices that are tolerated by young children both inside and outside the lab (see Smith, Yu, Yoshida, & Fausey, 2015, for an overview).

## Capturing egocentric views of objects

Recent innovations in a lightweight wearable camera system have made it possible to capture the first person views of young infants and children. There are now a number of researchers conducting studies in which the child's own view is recorded and analyzed, and different setups have been developed to address different research questions. A typical setup for the lab setting includes multiple room cameras, which can include a wall-mounted camera for a side view of the scene and a ceiling camera for a bird's-eye view.

The cameras are often selected to be high-resolution digital cameras able to capture fast motion between frames. For the dynamic first person views, researchers use either a mini head camera or eye-tracking headgear. These are placed on the infant's forehead with a cap, headband, and/or glasses frame. The head camera or eye-tracking headgear is small and lightweight – typically weighing between 48g and 83g (for a head camera ~20–30g). Head cameras use a single camera recording the visual field from the infant's perspective (e.g., ~75° diagonal, ~70° horizontal, ~50° vertical); eye-tracking headgear also uses another camera facing the infant's right eye to record the eye's movements. The infrared LED facing the infant's right eye tracks the pupil and corneal reflection in addition to the camera recording the visual field from the infant's perspective (Franchak, Kretch, Soska, & Adolph, 2011). After placement of the camera(s) on children's heads, both the head camera and the eye-tracking methods take care to calibrate the views. For example, a manual calibration procedure uses a board and displays some spatially distributed stickers, and gaze direction is calibrated at the beginning and end of a task session by the experimenter pointing to each sticker to attract the infant's attention to that point in the image space. The same procedure can be used for all ages of participants, and any portion of the process can be automatized. Videos along with audio data are often joined and synchronized (either on-line or off-line, and time locked at the appropriate rate) to show the multiple views, including the first person view with eye-tracking coordinates superimposed over the image (circle indicating the fixation as shown in Figure 7.1, top-right) for later annotation. A number of laboratories now have extensive experience using these kinds of systems and procedures, and report high success rates of placing and calibrating the eye-tracker with multiple age groups of participants.

The images in Figure 7.1 illustrate the views in front of infants and toddlers recorded by these systems. They are different from what a camera positioned on the ceiling or a tripod captures. In these views, objects are often brought up close to the child, largely viewed by the child (Smith et al., 2015; Yu & Smith, 2012), and differ from third person perspective scenes (Aslin, 2009; Yoshida & Smith, 2008; Yurovsky, Smith, & Yu, 2013). Also, visual experience is intimately tied to body and movement. Every eye-gaze direction shift, every head turn, every hand action, every step taken changes the information available to the visual system. Many studies have demonstrated that early visual experiences are indeed influenced by the size and morphology of the infant body, and what they can do with that body (James, Swain, Jones, & Smith, 2014; Kretch,



*Figure 7.1* Egocentric scenes captured from head-mounted scene cameras in the lab.



*Figure 7.2* Egocentric scenes during everyday activities at home.

Franchak, & Adolph, 2014; Pereira, James, Jones, & Smith, 2010). These views are also different from views that reach adult eyes, with adult heads on adult bodies and adult motor repertoires (Smith, Yu, & Pereira, 2011), and thus they are not easily predicted by adult intuitions (Franchak et al., 2011; Yurovsky et al., 2013). Across studies using different cameras, in different contexts, with different ages, it is now clear that the young learner's egocentric view differs dramatically from other views. The contents of the egocentric view are essential for researchers to understand what visual object information is available to young learners.

An exciting development in recent years has been to capture egocentric views not only in the lab, but also in everyday contexts at home (Fausey, Jayaraman, & Smith, 2016; Jayaraman et al., 2015; Smith et al., 2018; see also Bergelson & Aslin, 2017). This method prioritizes the everyday scenes that infants encounter, and yields datasets of egocentric views that are not distorted by the presence of an experimenter or pre-designed tasks. By using a lightweight camera with sufficient battery life and video storage, and that parents can easily position on their child, we can discover the content of everyday scenes and how this may change over development (see Figure 7.2).

## Discoveries with egocentric object views

Over the past decade, we have learned a great deal about how visual input matters for early word learning by outfitting infants and toddlers with egocentric cameras during object play and naturalistic activities. One lesson is that the sensory input from the toddler's point of view is selective (Clerkin, Hart, Rehg, Yu, & Smith, 2017; Smith et al., 2011; Yoshida & Smith, 2008), and object names associated with these selective views are especially transparent and likely to be learned (Pereira, Smith, & Yu, 2014; Yu & Smith, 2012; Yurovsky et al., 2013). Figure 7.3 illustrates the dramatic difference in the visual information available to a toddler interacting with an object compared to the room view.



*Figure 7.3* Egocentric (left) and room (right) views synchronized in time.

One major gate to these egocentric views is the toddler's own action. Toddlers have short arms, so when they hold an object it is close to their eyes and dominates over potential competitor objects (Smith et al., 2011). Further, toddlers move their heads less when holding an object (Smith et al., 2011) and when reaching for an object (Yoshida & Smith, 2008) compared to other moments, and so they create a relatively stable view. We now know that this uncluttered and stable view facilitates object name learning: toddlers are more likely to learn an object's name if they hear it while they are holding the object that is large-and-stable in view compared to other moments (Pereira et al., 2014; Yu & Smith, 2012). Another gate to the egocentric views emerges through social context where these views are made available by parents to infants who are still learning to reach efficiently and manipulate objects (Burling & Yoshida, 2019). In a semi-longitudinal study, infant's object fixation was tracked as a function of object manipulation by child and/or parent with 5- to 24-month-olds. The results suggest a robust sustained attention before they actively manipulate objects throughout the developmental transition between parent-generated and self-generated exploration of objects.

Further, toddlers' self-generated visual experiences may be central to development of visual object recognition. Pereira et al. (2010) reported developmental changes in how toddlers hold objects during visual exploration, across the same developmental period as the normative vocabulary burst. In this study, 12- to 36-month-old children first participated in visual and manual exploration of held objects and then later completed an object recognition test with sparse geometric versions of those objects. Pereira et al. (2010) reported that older children (but not younger children) showed a preference for planar view in which the major axis of the object is parallel to the line of sight (James, Humphrey, & Goodale, 2001) and an increasing sensitivity to the geometric structure of the objects, which has been linked to the number of nouns in their productive vocabularies (Pereira & Smith, 2009; Smith, 2003). Further correlational evidence suggests a link between infants' object exploration and object recognition by showing that 5- to 8-month-old infants' history in sitting, holding, and visually exploring objects predicts their ability to recognize an object from a previously unseen view (Soska, Adolph, & Johnson, 2010). These studies together point to an emerging consensus that developmental processes involving visual object recognition and the way young children hold and manipulate objects are tightly linked (Bertenthal & Clifton, 1998; Needham, 2000; Rochat, 1989) and may play a critical role in early object name learning (Smith, 2013).

A second lesson from recent analyses of young children's egocentric views is that the set of views available to toddlers may be an especially useful object recognition "training dataset". Variable views of single objects, together with a highly non-uniform distribution of views across objects, may be computationally advantageous to early learning. Several recent studies demonstrate the value of the natural visual experiences that toddlers create for themselves when holding objects. Yu, Bambach, Zhang, and Crandall (2017) showed that state-of-the-art machine learning algorithms (Simonyan & Zisserman, 2014) learned to recognize objects in new contexts more successfully when trained on toddler views than adult views. This generalization success could be attributed to the variability in views (Simonyan & Zisserman, 2014). Slone, Smith, and Yu (2017) pursued this hypothesis and reported that greater variability in self-generated views at 15 months of age predicted the number of object names that toddlers knew 6 months later (see Montag, Jones, & Smith, 2015; Perry, Samuelson, Malloy, & Schiffer, 2010, for the potential processes). Clerkin et al. (2017) also recently reported that everyday scenes of one activity (mealtime) are highly cluttered, but within this clutter there is a small set of repeating objects. These most pervasive objects are also among the earliest named objects according to vocabulary

norms. We now know that specific properties of the egocentric views available to young children are quite different from the typical "visual diet" fed to computer vision algorithms, which presents exciting opportunities for collaboration and future insights in both developmental and computer science (see Smith & Slone, 2017, for further discussion).

Finally, a third lesson revealed by capturing and analyzing young children's egocentric views is that these views change over time. In the social domain, young infants see many more faces than hands, while toddlers see many more hands than faces (Fausey et al., 2016). The properties of scenes with early named objects also change over time, with 8 to 10-month-olds encountering views relatively cluttered with objects, and toddlers encountering more selective object views (Clerkin et al., 2017; Smith et al., 2018). These discoveries highlight the need to take changing input into account in our theories of developmental change.

## Implications and future directions

We return to a foundational question for theories of language learning: What supports linking heard names to seen objects? How do recent discoveries based on egocentric views of objects guide next steps for studying the role of visual attention, memory, and learning in language development? We suggest that researchers are now in an excellent position to link the statistical structure of encountered objects to the available linguistic input, and to examine how the visual and linguistic streams may vary across contexts and learners.

Evidence from adults and children suggests that speech and eye movements are strongly coupled (Borovsky, Elman, & Fernald, 2012; Griffin & Bock, 2000; Tanenhaus, Spivey-Knowlton, Eberhard, & Sedivy, 1995). For example, Griffin and Bock (2000) demonstrated that speakers have a strong tendency to look toward objects referred to by speech and that words begin roughly 1 second after speakers gaze at their referents. Developmental studies in controlled lab settings document that heard words guide attention throughout development in a variety of task contexts (e.g., preferential looking, word comprehension, visual search, and sentence processing, among others). Recent studies have shown the power of words to direct visual attention in infants as young as 6 months old (Bergelson & Swingley, 2012; Tincoff & Jusczyk, 2012). Other studies have shown that 3-year-old children are faster to find objects in cluttered scenes if they are cued with the object name than if they are cued with the object picture (Vales & Smith, 2015), suggesting that labels play a role in children's visual working memory representations and visual target identification. What is the origin of this linguistically mediated attention and object recognition, and how robust is it?

We do not yet know the origins or developmental pathways that support linguistically cued attention, but the multimodal structure of the encountered input is likely relevant. The idea that statistical regularities are a strong (so-called top down) force on attention is a critical component of all influential models of attention (Desimone & Duncan, 1995; Egeth & Yantis, 1997; Fecteau & Munoz, 2006; Hayhoe & Ballard, 2005; Treisman, 2009; Wolfe, 2007), but we are only beginning to understand these regularities in infants' experiences. What are the words that co-occur with the egocentric views of objects, especially in everyday contexts? Perhaps parents' object handling helps to organize co-occurring sounds, supporting phonological segmentation and word-referent mappings for specific objects. Or developmentally ordered input like massive repetition of visual objects for months before the objects' names are encountered may support rapid learning of multiple words during the typical toddler "word burst" period. The power of a word to direct attention may depend on its multimodal history, and vary across the early years as children build their vocabularies. Determining the extent to which visual and linguistic streams offer concurrent and/or ordered support for linking objects and their names will

constrain theories about the origins of linguistically cued attention. The head camera approach will help researchers discover the microstructure of moment-to-moment instances in which a word meets its visual scene, creating a history of language-vision co-occurrences that may support linguistically cued attention.

Clearly, the power of a word to direct attention is important in many contexts – from learning words, to finding relevant parts of a scene, to following instructions in a classroom. However, as for robustness, we know relatively little about potential individual differences in the developmental trajectories of linguistically cued attention. Can a single utterance effectively direct attention in all children, or could multiple repetitions of the same word be required for some children? Individual differences in the suite of early visual, language, social, and attentional experiences are particularly relevant for understanding the robustness of linguistically cued attention in typical and atypical development.

A growing number of studies indicate that individual differences in the ability of 6- to 18-month-olds to establish joint attention are strongly predictive of language ability at 24 to 36 months (Markus, Mundy, Morales, Delgado, & Yale, 2000; Morales, Mundy, & Rojas, 1998). Mundy and colleagues have been particularly interested in the early diagnosis of children with autism spectrum disorders (Delgado, Mundy, Crowson, Markus, Yale, & Schwartz, 2002). The task they used is similar to those that are used to measure the extent of the perceptual field. In this task, a target that is socially indicated by a parent's gaze direction or point is located within or outside of the visual field, and children's gaze shift to that target is recorded from a room camera facing the child. Typically developing children (12 to 18 months) readily follow eye gaze (or point) to a target outside of the visual field. Mundy and colleagues have used performance in this task to predict children at risk for difficulties in learning language, and children with autism show specifically marked difficulties in the use of social cues in this task. Interestingly, however, a recent study in which parents and their young children with autism wore head cameras during a social interaction documented parental scaffolding that supported the child's sustained attention to referential cues and joint attention (Yoshida & Kushalnagar, 2009). In this study, children with autism experienced joint attention moments at a similar rate as their typically developing peers. They also experienced more joint attention moments than their typically developing peers immediately after parents gestured. Parents appear to alter their behavior according to the developmental level of their child, including increased scaffolding for their children with autism, with measurable consequences for the child's visual experiences in social interactions. Head cameras are particularly well suited to address questions about visual patterns of cause and consequence,



*Figure 7.4* Egocentric (left) and room (right) views synchronized in time taken from deaf parent-child dyads.

feedback loops, and coordination in dyadic play (see also Yu & Smith, 2016), with clear public health relevance and the potential to guide evidence-based supportive parenting interventions.

Autism research has also reported links between atypical sensorimotor development and atypical patterns of object exploration (de Campos, Savelsbergh, & Rocha, 2012), visual processing (Behrmann, Thomas, & Humphreys, 2006), and attention (Takarae, Luna, & Sweeney, 2012), indicating potential cognitive factors constraining visual experiences. The co-occurrence of words and referents with these atypical visual experiences, and the predictability structure of the input, may also be atypical – leading to different and challenging trajectories of both word learning and linguistically cued attention. Recent studies using head cameras to capture interactions between parents and children, however, highlight a wide range of co-occurrence and predictability structures relating the linguistic and visual streams within experiences of *typically developing children* (Castellanos, Pisoni, Yu, Chen, & Houston, accepted; Yoshida & Kushalnagar, 2009). In one study, egocentric viewing by typically developing 3- to 5-year-old deaf children (of deaf parents) was recorded in a social interaction with objects (Yoshida & Kushalnagar, 2009). The preliminary results indicate that during interactions between a child and a parent whose linguistic input is visually encoded dominantly (e.g., American Sign Language), the parent's hands and the child's own hands dominate the child's visual experiences (see Figure 7.4). Compared to hearing children, single object play is also especially apparent. Hence, egocentric views may reveal not only potentially atypical encounters with visual objects, but also the ways in which these encounters and the coordination of visual, language, and social input support multiple pathways of language development. Egocentric views reveal properties of the visual environment that are available to young learners and therefore available to shape their attention and learning (see Jayaraman, Fausey, & Smith, 2017, Figure 7.1). Insights into the structure of this input, and its variation across typical and atypical development, will advance our understanding of how learning emerges and changes, and guide future interventions designed to support strong beginnings of language development.

## Conclusion

Children learn to talk about objects. Recent efforts using head cameras have captured the visual objects that young learners actually encounter. We have learned that these egocentric scenes are often selective with respect to the objects in view, change over developmental time, and have properties that are computationally advantageous to early learning. We look forward to future discoveries about the linguistic and social cues that co-occur with egocentric views in order to support early language learning in many kinds of learners in many kinds of contexts.

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# 8

# A ROLE FOR SLEEP IN UNDERSTANDING LANGUAGE ACQUISITION

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## Introduction

On the surface, sleep and language would seem entirely unrelated. However, there are at least three reasons we should consider how sleep intersects with language acquisition. First, variations in sleep appear to influence language outcomes (Bernier, Carlson, Bordeleau, & Carrier, 2010; Dearing, McCartney, Marshall, & Warner, 2001; Dionne, Touchette, Forget-Dubois, Petit, Tremblay, Montplaisir, & Boivin, 2011; Horváth & Plunkett, 2016; Lam, Mahone, Mason, & Scharf, 2011; Touchette, Petit, Séguin, Boivin, Tremblay, & Montplaisir, 2007). Second, sleep plays a fundamental role in memory formation. If we are to identify and understand the learning and memory mechanisms supporting language acquisition, we must understand the role of sleep in retention of new language learning (Gómez, 2017). Third, there is reason to think that sleep supports consolidation of new memories differently in infants and toddlers (Gómez & Edgin, 2015), with implications for theories of language acquisition (Gómez, 2017). Although entire literatures focus on word learning, statistical learning, and language acquisition, we do not as a field have a unified theory of how children acquire language over time. Such a theory should surely explain how language learning changes as the brain develops and as children gain experience with their language. Although we do not offer such a theory here, we review the literature on sleep-dependent memory formation to provide insight regarding this issue.

We will address the following topics in the ensuing pages. First, we will describe the development of sleep. Next, we will describe work investigating the relationship between daily sleep in early development and vocabulary at older ages, followed by experimental work investigating the effects of daytime and nighttime sleep on retention of new language learning in children. We will then investigate links between developmental language delay and sleep. In the final sections we will describe theories addressing how sleep supports memory consolidation and how children's brain development at different ages may constrain the nature of their memory formation. We will end with a discussion of the implications of these constraints for how children acquire language.

## Development of sleep

Newborns exhibit three stages of sleep: quiet sleep, active sleep, and indeterminate sleep (Stockard-Pope, Werner, & Bickford, 1992). Quiet and active sleep will become identifiable stages of

non-rapid eye-movement (NREM) sleep and rapid eye-movement (REM) sleep by about 3 months of age (Anders, Keener, & Kraemer, 1985). Indeterminate sleep reflects transitions between quiet and active sleep and disorganized electroencephalogram (EEG) activity. By about 3 months of age, brain oscillations mature such that infants show identifiable stages of NREM1–3 and REM in their EEG. NREM1, the lightest stage of sleep, represents the transition from wakefulness to sleep, followed by increasingly deeper stages of NREM2 containing short 2–3 second bursts of high-frequency thalamo-cortical spindle activity (11–15 Hz) associated with memory formation in adults (Fogel & Smith, 2011; Clemens, Fabó, & Halász, 2005; Schabus et al., 2004; Tamminen, Payne, Stickgold, Wamsley, & Gaskell, 2010; Tamminen, Ralph, & Lewis, 2013) and children (Friedrich, Wilhelm, Born, & Friederici, 2015; Friedrich, Wilhelm, Mölle, Born, & Friederici, 2017; Kurdziel, DuClos, & Spencer, 2013; Smith et al., 2018) and NREM3 containing high-amplitude, low-frequency delta activity, known as slow-wave activity (0.5–4 Hz), also associated with memory formation in adults (Holz et al., 2012; Daurat, Terrier, Foret, & Tiberge, 2007; Drosopoulos, Wagner, & Born, 2004; Marshall, Mölle, Hallschmid, & Born, 2004), infants (Simon et al., 2017), and children (Smith et al., 2018).

Sleep occurs in distinct cycles throughout the night beginning with descent into increasingly deeper phases of NREM sleep (NREM1, NREM2, NREM3), then ascent through lighter phases of NREM (NREM2, NREM1) and REM sleep before re-descending into NREM3 and continued cycling throughout the night. Very young infants initially may fall directly into REM for a brief period before transitioning to NREM. Also, initially, sleep spindles do not synchronize well bilaterally, but by 12 months of age spindles synchronize bilaterally about 70% of the time (Dan & Boyd, 2006; de Weerd & van den Bossche, 2003; Ednick et al., 2009; Ellingson & Peters, 1980). By 2 years of age spindles synchronize consistently.

Later developments in child sleep include a gradual transition from multiple daytime naps and a longer period of nighttime sleep in infancy to one period of nighttime sleep by age 5 years for most children (Davis, Parker, & Montgomery, 2004). Additionally, at approximately 60 minutes in duration, children's sleep cycles are shorter than those of adults at age 3 but lengthen to adult durations of approximately 90 minutes by age 5 (Sheldon, 2002). Young children also show developmental changes in NREM and REM sleep. Young children have high intensity of the slow oscillations in NREM3 that stays high until age 11–12 when it drops precipitously over the next several years, by 66% by age 17 (Feinberg, 1974). Children also show higher percentages of NREM than adults until roughly 10 years of age when this percentage diminishes. REM decreases from about 40% of sleep at 3–5 months to 25% of sleep by 2–3 years and to 18.5% by 12 years (Roffwarg, Muzio, & Dement, 1966).

## Variations in sleep influence language outcomes

In this section, we ask how the amount of daytime and nighttime sleep affects vocabulary outcomes. We also address how external factors, such as socio-economic status (SES), may impact these associations. We consider sleep variation an important research question given estimates that sleep problems exist at levels as high as 20%–41% of children (Archbold, Pituch, Panahi, & Chervin, 2002; Mindell, Owens, & Carskadon, 1999; Owens, Spirito, McGuinn, & Nobile, 2000). Furthermore, as the following pages show, poor sleep is associated with poor language outcomes.

Horváth and Plunkett (2016) examined napping behavior and its relationship to vocabulary using a multi-level modeling approach. They assessed sleep and vocabulary between ages 7 and 37 months using the Sleep and Naps Oxford Research Inventory (SNORI), a parent-report sleep diary designed to track a child's sleep for 10 days, and the Oxford Communicative

Development Inventory (OCDI). Follow-up vocabulary assessments occurred 3 and 6 months later. At the initial assessment, sleep efficiency, defined here as the proportion of the nighttime sleep duration actually spent asleep (adjusted for nighttime awakenings), correlated positively with receptive vocabulary. Additionally, both sleep efficiency and number of daily naps correlated positively with expressive vocabulary. Regarding growth of vocabulary over time, children who took more naps and those with greater sleep efficiency showed a higher rate of change in receptive vocabulary. The authors argue that these findings are consistent with the idea that infants' memory systems may be more susceptible to interference, and thus more frequent naps may allow infants to appropriately consolidate new information. Indeed, work with adults shows that newly encoded memories are susceptible to interference and forgetting across periods of wakefulness (Diekelmann, Wilhelm, & Born, 2009), an effect that diminishes the closer sleep occurs after learning (Payne et al., 2012; Gais, Lucas, & Born, 2006; Talamini, Nieuwenhuis, Takashima, & Jensen, 2008). We see a similar pattern in work with infants and children, demonstrating a stronger memory benefit when sleep occurs shortly after learning (Hupbach, Gómez, Bootzin, & Nadel, 2009; Backhaus, Hoeckesfeld, Born, Hohagen, & Junghanns, 2008; Sandoval, LeClerc, & Gómez, 2017; Werchan, Kim, & Gómez, 2016; Williams & Horst, 2014). Interestingly, Horváth and Plunkett (2016) find that total nighttime sleep correlates negatively with predicted expressive vocabulary growth, such that children with more nighttime sleep show slower growth in expressive vocabulary. Although the authors subtracted the amount of time children spent in nighttime awakenings from nighttime sleep duration, this measure may reflect a relationship between less efficient nighttime sleep and worse vocabulary, though more total nighttime sleep could also reflect less napping. Thus, the factors underlying the relationship between total nighttime sleep and expressive vocabulary remain unclear.

Although Horváth and Plunkett (2016) observed positive associations with the number of daily naps and language outcomes in infancy, studies with older preschool-age children link napping behavior with cognitive immaturity. Lam et al. (2011) examined the relationship between both daytime and nighttime sleep and various cognitive measures including vocabulary. Children ages 3–5 years wore actigraph watches, measuring body movement, for 7 continuous days, and parents filled out daily sleep diaries. Children also completed a series of neuropsychological tests including the Peabody Picture Vocabulary Test (PPVT). Napping correlated negatively with measures of vocabulary, leading the authors to suggest that nap cessation may indicate more advanced brain maturation. However, children who are napping more may be doing so in response to poor nighttime sleep, which could in turn contribute to long-term cognitive reductions in vocabulary. The children in this study slept an average of 8.5 hours per night, several hours short of the average amount of sleep for this age (Mindell & Owens, 2015; Bathory & Tomopoulos, 2017). Touchette et al. (2007) linked nighttime sleep with later vocabulary outcomes. Here, the authors obtained parent-reported nocturnal sleep duration at ages 2.5, 3.5, 4, 5, and 6 years and scores on the PPVT at age 5. In the analysis of the longitudinal sleep data, four distinct developmental sleep patterns emerged – *short persistent* (children who slept less than 10 hours per night), *short increasing* (children who had short sleep early in life, but sleep duration increased to typical levels by around 41 months), *10-hour persistent* (children who slept around 10 hours each night) and *11-hour persistent* (children who slept around 11 hours each night). Importantly, children with short persistent nighttime sleep showed worse PPVT performance at age 5. At age 10, this group of children was 2.67 times as likely to have poor vocabulary outcomes as children in the 11-hour persistent group (Seegers et al., 2016). Although children in the 10-hour persistent group did not show a vocabulary deficit at 5 years, however, they were 1.66 times more likely to have poor vocabulary at age 10 than the 11-hour group. Such

findings strongly suggest that chronic short nighttime sleep during childhood can inhibit language acquisition (Touchette et al., 2007; Seegers et al., 2016).

Other research focuses not only on the duration of nighttime sleep, but on the ratio of daytime sleep to nighttime sleep. This ratio, reflecting the degree to which sleep consolidates over the nighttime vs. the daytime hours, indicates maturation (with a lower number indicating greater maturity). In one study, 12-month-olds with a greater percentage of their sleep occurring at night showed larger expressive vocabularies as assessed by the MacArthur Communicative Developmental Inventory (MCDI) at 26 months (Bernier et al., 2010). Similarly, in a large-scale twin study, Dionne et al. (2011) examined sleep and language development early in life. They obtained daytime and nighttime sleep duration from parent-reported sleep at ages 6, 18, and 30 months and derived daytime/nighttime sleep ratios. They also obtained measurements of expressive and receptive vocabulary at 18 and 30 months using the MCDI and at 60 months using the PPVT. Children with more mature sleep at 6 and 18 months had better language skills when assessed at 30 and 60 months. Furthermore, 57% of children with persistent and 62% of children with late onset language delays had higher daytime/nighttime sleep ratios (i.e. they were getting more of their sleep during the day) than average at ages 6 and 18 months. However, in this study, 90% of children with transient language delays (children who were delayed at 18 months but not at 60 months) had average or better than average sleep consolidation at 6 and 18 months. This led Dionne et al. (2011) to suggest that developmentally earlier sleep consolidation may be a protective factor for children who experience early language delays. Dionne et al. (2011) also conducted genetic analyses to examine the relative contributions of genetic and environmental factors to the relationship between language and sleep. The degree of sleep consolidation at 6 months (reflected in the daytime/nighttime sleep ratio) was found to be highly heritable, with 64% of the differences in sleep consolidation attributed to genetic factors. At 18 months, shared environmental factors explained more of the variability in sleep consolidation (58%). Language outcomes were modestly heritable and mostly due to shared environment. Further, the relationship between sleep consolidation and language development showed high heritability at 6 months (i.e. genetic factors explain the association between sleep consolidation and later language outcomes early in life), but this influence appears to shift, with shared environmental factors playing a larger role across later development.

A factor not taken into account in the studies reviewed thus far is the regularity in children's sleep patterns; however, circadian rhythm modulation correlates with language development. Dearing et al. (2001) measured circadian rhythm regulation in infants and found that infants with more rhythmic sleep at ages 7 and 19 months had superior language skills at 36 months.

Although the findings reviewed above may seem contradictory, it is important to consider the influence of external factors on sleep consolidation. Dearing et al. (2001) propose two paths to rhythmic sleep. The first, child-regulated circadian sleep, represents sleep consolidation that occurs purely as a result of the child's maturation. The second, parent-regulated circadian sleep, acknowledges that parental factors, like parents' perception of their child's temperament and parental education, may play a role in sleep regulation as well, as some parents may be more likely to impose rhythmicity on their child's sleep. Dearing et al. (2001) predict that child-regulated circadian sleep would be a better predictor of language and cognitive outcomes.

A range of external factors may play a role in children's sleep consolidation, which would in turn influence the relationship between sleep and language outcomes. Early in life, parental factors (e.g. co-sleeping, the degree with which parents support consistency in sleep schedules, etc.) may influence the quality and rhythmicity of an infant's sleep. By preschool age, other external factors may influence sleep consolidation, like inconsistent parent/family schedules or children desiring more autonomy in their sleep schedule. The degree of the influence of external factors

on sleep consolidation may change across development as well, which could further cloud the relationship between sleep and language outcomes. For example, in infancy, brain maturation may be a strong driver of sleep consolidation, consistent with the findings of Dionne et al. (2011). However, as children age, they may choose to stay up later, which would truncate their night sleep. This would likely result in more napping during the day, which would appear as less mature sleep consolidation. Thus, a preschooler's sleep could appear less mature due to the child's developmental state or external factors.

The degree of the influence of external factors on sleep consolidation may also change across development, which could further cloud the relationship between sleep and language outcomes. Environmental factors heavily influence nap duration, whereas genetic factors mostly influence nighttime sleep duration (Touchette et al., 2013). During early childhood, external factors like parental attitudes toward napping (Jones & Ball, 2013), mandatory naptimes in child care settings (Staton, Smith, Pattinson, & Thorpe, 2015), and home environment (McDonald, Wardle, Llewellyn, van Jaarsveld, & Fisher, 2014) all influence sleep patterns. Furthermore, children with inconsistent sleep practices at bedtime have less sleep at night and compensate for their shorter nighttime sleep with daytime napping (Jones & Ball, 2014). Considering the various factors that influence sleep patterns in preschool-age children may help clarify the relationship between sleep and language outcomes. Similar to Dearing et al. (2001), perhaps only sleep consolidation due to maturation would be predictive of language and cognitive outcomes.

The established links between SES, language exposure, and language outcomes (Hart & Risley, 1995) also make SES and language exposure important factors to consider. Although most of the studies reviewed above did not control for SES, Touchette et al. (2007) still observed lower vocabulary outcomes at age 5 in children who persistently slept less than 10 hours per night over the years of the study after controlling for SES. Bernier et al. (2010) also reported better vocabulary outcomes for children with a more mature ratio of daytime to nighttime sleep as infants after controlling for SES. However, children from low SES homes ages 1–5 years had more nighttime awakenings, longer periods of wakefulness, and shorter periods of continuous nighttime sleep than children from high SES homes (Acebo et al., 2005). Also, fewer parents of young children from low SES homes have a bedtime routine or consistently use one (Hale, Berger, LeBourgeois, Brooks-Gunn, 2009; Jones & Ball, 2014). Setting a bedtime routine is a practice that results in longer nighttime sleep (Jones & Ball, 2014). Greater inconsistencies in the quality of sleep correlate with poorer academic achievement and poorer performance on intellectual measures (Buckhalt et al., 2009). Despite the link between SES and sleep, no studies to date investigate the link between the amount of language exposure in the home, SES, and sleep. Although low maternal education associated weakly with worse language outcomes in fifth grade children with sleep/wake problems, and high maternal education appeared to protect language outcomes, high paternal education had the opposite effect although high paternal education protected language outcomes in fifth grade if children varied in the times they awakened from day to day in third grade (Buckhalt, El-Sheikh, Keller, & Kelley, 2009). Given the conflicting relationships of maternal and paternal education for language outcomes for children with sleep/wake problems, and given the conflicting relationships of maternal and paternal education for language outcomes for children with sleep/wake problems, and the tendency for children from low SES homes to get less sleep, it will be important to determine the relationships among language input, SES, sleep, and language outcomes for purposes of intervention.

Other external factors contributing to changes in sleep patterns may interact with SES and may offer avenues for future intervention studies. For instance, the presence of an older child in the home and watching TV in the evening are associated with shorter nighttime sleep in preschool-age children (McDonald, Wardle, Llewellyn, van Jaarsveld, & Fisher, 2014), a situation

that may have an additive effect in combination with other factors affecting sleep in low SES homes. As noted earlier, parents in low SES homes allowed naps more than parents in high SES homes (Jones & Ball, 2013). To the degree that this practice compensates for insufficient sleep in preschool-age children, an intervention could be to restrict children's naps. Children in one study compensated for decreases in daytime sleep with increases in the duration of their nighttime sleep accompanied by increases in attentional control compared to a group who did not restrict naps (Lam, Koriakin, Scharf, Mason, & Mahone, 2015). Under such conditions, it could be important to reconsider the practice of mandatory naptimes for children who no longer need to nap (see Staton et al., 2015) and who may have insufficient nighttime sleep. Thus, factors in the home and in child care settings may interact with SES and sleep and may offer avenues for future interventions.

## Sleep plays a fundamental role in memory formation: effects of sleep on retention of new language learning from infancy through the school years

The literature reviewed above investigates associations between sleep and language outcomes acquired over months and years. However, sleep has more immediate effects on retention of new language learning. We review two lines of such research, one investigating sleep-dependent retention of statistical learning, the other investigating sleep-dependent retention of new word mappings.

### *Statistical learning*

By 8 months, infants rapidly segment novel words from running speech (Saffran, Aslin & Newport, 1996), and by 17 months, they can use newly segmented speech as a label for a referent (Estes, Evans, Alibali, & Saffran, 2007). These studies typically test learning within minutes of exposure to the novel materials. Although 6-month-olds discriminate newly segmented words vs. part words at immediate test (Thiessen & Saffran, 2003), they show no discrimination after a 1-hour period of wakefulness and poor discrimination after a 1-hour delay containing sleep. Retention correlated with slow-wave activity such that infants with more low-frequency NREM activity (range 1–10 Hz) showed a more mature pattern of retention (Simon et al., 2017). Consistent with this outcome, 8-month-olds demonstrated no retention of newly segmented words at a 10-minute delay unless they also heard the words in isolation after the segmentation phase of the study (Karaman & Hay, 2018). Thus, very young infants display fragile retention of newly learned speech information, even with sleep.

Retention of statistical learning becomes more robust by 15 months, with memory of a nonadjacent dependency seemingly intact after a 4-hour period of wakefulness (Gómez, Bootzin, & Nadel, 2006). Children heard strings like vot-kicey-rud, pel-wadim-jic, vot-wadim-rud and discriminated these at test, reflected in longer listening times to familiar strings than to strings violating the nonadjacent dependencies from training (e.g. vot-kicey-jic, pel-wadim-rud, vot-wadim-jic). After a 4-hour delay containing a nap, children treated the nonadjacent dependencies more abstractly. They listened longer on average to test trials conforming to the specific nonadjacent dependencies occurring in the first test trial than to test trials with nonadjacencies conflicting with those from the first test trial. Children appeared to detect specific nonadjacencies in the first test trial and retained this preference over the remainder of the test trials, suggesting that after sleep they retained the understanding that predictive relation occurred between the first and last word in each string but not the specific words encountered in that relation from training. This effect stemmed from prior learning, as a control group exposed to a stimulus

set that does not support detection of the nonadjacencies during familiarization did not benefit from sleep. Hupbach, Gómez, Bootzin, and Nadel (2009) replicated the design of Gómez et al. (2006) over a 24-hour delay. The nap group showed the abstraction effect the next day, whereas the group that stayed awake during the 4 hours after training showed no evidence of retention 24 hours later, suggesting that although 15-month-old infants can retain learning over a 4-hour wakefulness delay, naps factor crucially into long-term retention.

## *Word learning*

Sleep also contributes to retention of word learning in infants. Horváth, Myers, Foster, and Plunkett (2015) reported significantly better retention of two novel word mappings after a nap than after an equivalent 2-hour period of wakefulness in 16-month-olds. Infants who did not nap showed no retention. Infants this age also generalized to novel exemplars after a 2-hour delay containing a nap but not after a similar period of wakefulness (Horváth, Liu, & Plunkett, 2016).

Recent work also reports the contributions of sleep physiology to new word learning. Friedrich et al. (2015) trained infants ages 9–16 months on 8 object-label mappings and 8 category-label mappings, 16 words in total. Infants then napped or stayed awake for about 90 minutes. Children who napped showed an N200–500 word-priming effect for the object-label mappings, reflecting greater memory for the mapping between the referent and the word form after the nap than after a similar period of wakefulness. This group also showed an N400 effect for the category mappings, reflecting semantic integration that correlated with electroencephalogram (EEG) power in the spindle-frequency range (10–15 Hz). In a second study, memory effects strengthened with increased duration of the nap at 6–8 months of age (Friedrich et al., 2017). Infants with shorter naps showed increased perceptual memory for the object-label mapping reflected in a late negativity (592–1,054 msec) over central to parietal, and over left fronto-central and temporo-parietal brain regions similar to that observed in 3-month-olds (Friedrich & Friederici, 2017). In contrast, infants with longer naps showed a more mature N400 semantic integration effect with infants with greater EEG power in the spindle-frequency range showing greater N400 effects, further linking sleep to memory formation. Together, these studies showing better retention after sleep than after a similar period of wakefulness suggest that sleep plays an essential role in language acquisition in infancy.

Sleep also contributes to retention of new language learning in toddlers and preschoolers. Williams and Horst (2014) tested 3-year-olds who still napped habitually versus 3-year-olds who no longer napped. Children learned two new word mappings that occurred either in three different stories (three-story condition) or in three readings of the same story (one-story condition). Children heard and saw each of the novel label-object mappings four times in each story. Thus, they had exposure to each mapping in the same story contexts 12 times or in three different story contexts four times each. Although parents may read the same story to children more than once in one night, the three-story condition is more like what children may experience in the course of a day when they may hear novel vocabulary in more than one story or contextual setting. The experimenters probed children's memory for the word mappings immediately after training, and after 2.5-hour, 24-hour, and 7-day intervals. Habitual nappers showed the greatest retention, increasing their word-mapping accuracy after their nap in the one- and three-story conditions (peak accuracy = 90% and 79% respectively) and holding constant across the remaining test opportunities. Children in the one-story condition who were no longer napping and thus stayed awake after learning showed decreased word-mapping accuracy after the 2.5-hour wakefulness delay but rebounded to a peak level of accuracy of 87% after nighttime sleep that they maintained across the 7-day delay. Children in the three-story condition who no longer

napped habitually suffered a worse fate. Their peak level of accuracy of 38% did not deviate from chance responding even after nighttime sleep. Thus, although children who no longer nap showed robust retention of new word mappings with sufficient redundancy at encoding in the one-story condition, these children showed poor encoding and retention when hearing the words in varied contexts. The latter circumstances, resulting in deficits in memory for nonnapping children, are more similar to circumstances children are likely to encounter daily. A limitation of this study, and other seminal studies in the literature (e.g. Kurdziel, Duclos & Spencer, 2013), is that the authors tested the same children repeatedly. Although repeated testing of the word mappings in the same children is efficient from the standpoint of experimental design, repeated retrieval makes it difficult to disentangle the effects of sleep from the boost to memory stemming from repeated retrieval of the learned mappings (Bäuml, Holterman, & Abel, 2014; Roediger, & Karpicke, 2006).

Sandoval, LeClerc, and Gómez (2017) investigated generalization of sleep-dependent learning in habitual and nonhabitual nappers in a study that did not involve repeated testing. They tested 37-month-old children on their ability to generalize novel verb labels to new actors using a fully crossed nap/no-nap x nap habituality design and random assignment of habitual and nonhabitual nappers to nap and wakefulness conditions. Habitual nappers napped four or more times a week. Nonhabitual nappers napped three or fewer times per week. Children had four exposures to each of two novel label-action mappings, then were tested 24 hours later on their ability to detect the correct action performed by a novel actor. Children who napped in the 5-hour interval after training generalized knowledge of the verb mappings to the novel actor at the 24-hour delay. Children who did not nap in the 5-hour interval failed to generalize, even if they were nonhabitual nappers, supporting the idea that naps contribute to retention in the early preschool years even when children are no longer napping. Children tested immediately after encoding in a separate experiment applied the label correctly to the actors from training but could not generalize learning to novel actors. Thus, the nap contributed to children's ability to extend newly learned labels to a new actor the next day.

Naps also contribute to children's ability to integrate exemplars within a novel category. Werchan and Gómez (2014) exposed 30-month-olds to three novel exemplars from each of three novel categories. Category exemplars shared a shape but differed in color and occurred on different-colored backgrounds in a design meant to mimic learning a novel category across different contexts (e.g. seeing a dog in a field, at home, and in a car). Children are able to integrate exemplars at encoding by 42 months of age but not at 30 months (Vlach & Sandhofer, 2011). The children in Werchan and Gómez's (2014) study showed poor generalization to a novel instance of the exemplar on immediate test (replicating Vlach & Sandhofer, 2011) and after a 4-hour delay containing a nap but performed at 80% accuracy on the generalization test after a 4-hour period of wakefulness. Werchan and Gómez suggested that continued activities during wakefulness contributed to children forgetting the specific exemplar colors and backgrounds from training, leaving intact their memory for the consistent mapping between the label and the shape of the object, supporting children's ability to detect a novel exemplar in response to the category label at the 4-hour delay. In contrast, the nap consolidated children's already distinct exemplar representations, preventing later integration and generalization. Werchan, Kim, and Gómez (2016) investigated this interpretation by testing children 24 hours after training. Now, children who did not nap in the 4-hour interval after training showed poor generalization. In comparison, children who napped showed excellent integration and generalization. Werchan et al. also tested a group of children 4 hours post nap to rule out the possibility that wakefulness after the nap might aid generalization. It did not. Children in this group performed at chance levels. Werchan et al. thus hypothesized that the nap helped children retain memories long

enough so they could benefit from nighttime sleep. Once in nighttime sleep, multiple iterations of NREM may contribute to integration of the exemplars (see Lewis & Durrant, 2011). REM also occurs at higher levels in nighttime sleep than in naps and thus may contribute to integration (see Poe, 2017). A caveat regarding the design used in Vlach and Sandhofer (2011) and Werchan and Gómez (2014) is that children did not select referents from between two newly learned referents. Instead, they selected the referent from among a familiar object, an unknown object, the referent, and a distractor (an item shown but not named during training). Thus, children's performance may not reflect word learning per se as much as their ability to detect a newly mapped object. However, the nap was crucial for stabilizing the new memories enough for children to benefit from further processing during nighttime sleep.

Although we know little about sleep-dependent changes in word learning in kindergarten and the early school years, a growing literature shows contributions of sleep to word learning in the later school years. In children ages 6–12 ($M$ = 9.31 years) who learned names for animals, recall of the animal names improved over nighttime sleep compared to periods of daytime wakefulness (Ashworth, Hill, Karmiloff-Smith, & Dimitriou, 2014). Sleep benefited recognition and recall of novel phonological word forms, such as *biscal* in children ages 7–12 years ($M$ = 9.62 years; Henderson, Weighall, Brown, & Gaskell, 2012). Sleep also contributed to integration of the word form into lexical networks, reflected in a slowed response to *biscuit* relative to a control word without a novel phonological neighbor (see also Henderson, Weighall, Brown, & Gaskell, 2013), whether children learned in the context of a phoneme monitoring task (Henderson et al., 2012, 2013), after learning science definitions for the novel word forms (Henderson, Weighall, & Gaskell, 2013), or after acquiring the meanings of the novel words implicitly through story reading (Henderson, Devine, Weighall, & Gaskell, 2015). Children in Henderson et al. (2015) with larger vocabularies showed greater lexical integration effects after a 24-hour delay containing sleep, even with variance for age removed from the analysis (see also James, Gaskell, Weighall & Henderson, 2017). Prior vocabulary predicted lexical integration even after controlling for Day 1 performance, suggesting that prior knowledge factored into the overnight consolidation of new word information. Smith et al. (2018) further investigated the relationship between sleep and word learning, reporting associations of greater overnight cued recall of the word forms and greater slow-wave activity (reflecting the intensity of the slow waves), and between recall and spindle power (reflecting the squared magnitude of the spindles). Smith et al. also reported associations between improvements in lexical integration and spindle power.

It is not clear when sleep-dependent word learning reaches adult levels. On the one hand, children show similar patterns of overnight consolidation and lexical integration (Dumay & Gaskell, 2007; Gaskell & Dumay, 2003; Henderson et al., 2012). On the other hand, children and adults may benefit differently from different factors, as proposed by James et al. (2017). Children may have an advantage in overnight consolidation due to having more high-intensity slow-wave sleep (SWS) than adults (Feinberg & Campbell, 2010; Ohayon, Carskadon, Guilleminault, & Vitiello, 2004; Wilhelm et., 2013). Furthermore, children have higher-intensity slow-wave activity that decreases from childhood through adolescence in 8–19-year-old children in tandem with decreases in cortical gray matter associated with pruning (Buchman et al., 2011). Children and adolescents also have higher sleep-spindle density compared to adults (Nicolas, Petit, Rompre, & Montplaisir, 2001). However, adults benefit from having larger, more extensive vocabularies (James et al., 2017). Although children achieved higher overnight levels of recall and lexical integration compared to adults in one study (Weighall, Henderson, Barr, Cairney, & Gaskell, 2016), other comparisons resulted in mixed outcomes (Henderson, Weighall, & Gaskell, 2013, 2015), raising questions for future research.

## A role for sleep in language impairment?

Next, we ask whether deficits in sleep-dependent consolidation factor into deficits in language learning in populations with developmental language disorder (DLD) manifesting in grammatical, morphological, and lexical deficits. Given the prevalence of DLD, which occurs in 7% of kindergarteners (Tomblin et al., 1997), and the fact that poor vocabulary predicts poor reading comprehension and academic achievement (Beck et al., 1982; McKeown et al., 1983; Stahl, 1983), we ask whether sleep promotes memory formation to the same degree in DLD as in typical language users. We noted earlier that 90% of infants with transient language delays at 18 months that resolved by 60 months had more mature daytime/nighttime sleep ratios at 18 months (Dionne et al., 2011), suggesting that more mature sleep may protect against language impairment. Furthermore, Earle, Landi, and Myers (2018) note reports of atypical sleep EEG in children with language impairments (Autret, Lucas, Degiovanni, Toffol, & Billard, 1992; Picard et al., 1998), making sleep an important issue to consider.

Consistent with abnormalities in their EEG, 5-year-old children with DLD showed impaired overnight retention in the production of a novel grapho-morpheme symbol compared to typically developing children of the same age and visual skill integration level (Adi-Japha et al., 2011). Adi-Japha and Abu-Asba (2014) extended this observation, showing that children with DLD had more daily loss in their speed at writing the novel grapho-morpheme symbol than typically developing children over four training days until the fourth day when speed between the two groups converged. Despite this convergence in performance, children with DLD showed much greater loss in speed over a longer 10-day delay than over the earlier 24-hour delays. Typically developing children showed no loss in speed over the 10-day period. Additionally, children with DLD showed statistically lower levels of accuracy than typically developing children across all days of the study. In a study of older 10-year-olds, those with DLD showed poor retention of sequential reaction time learning compared to typically developing controls after a 3-day consolidation period (Hedenius et al., 2011). Finally, Earle, Landi, and Myers (2018) trained adults on novel speech sounds, measuring perceptual accuracy and neural event-related potential (ERP) responses to the speech sounds over a 24-hour delay. Participants with DLD encoded new learning to the same degree as typical learners as measured in their ability to identify and discriminate the novel speech sounds immediately after initial encoding but showed no benefit from overnight consolidation, reflected in poor discrimination compared to typical learners who experienced increases in discrimination performance the next day. This outcome led Earle et al. to conclude that learners with DLD may have impaired ability to consolidate acoustic-phonetic information. Taken together with deficits in motor speed noted in Hedenius et al., Adi-Japha et al., and Adi-Japha and Abu-Asba, impaired identification and discrimination may detract from the accuracy and speed with which language users can process language in real time.

Another line of work suggests that adult learners with DLD show poor encoding of word forms relative to typical learners but no loss over 24-hour and 1-week delays in their retention of the word forms (McGregor, Arbisi-kelm, & Eden, 2017a; McGregor, Gordon, Eden, Arbisi-Kelm, & Oleson, 2017b), supporting the idea that difficulties in learning in DLD occur at encoding but not during consolidation. Furthermore, methods that improve word-form encoding, such as cued and uncued recall of word forms with feedback (McGregor et al., 2017b) or attention to the word-form features during training (McGregor et al., 2017a), also improve consolidation profiles. Impaired language learners also show lexical integration of the novel word forms, adding to the idea that they exhibit intact consolidation (McGregor et al., 2017a, 2017b). Finally, similar effects hold in younger learners with DLD. Children ages 7–11 showed deficits

in mapping new word-form labels onto referents that persisted across 3 days of testing compared to typical age-matched learners (Bishop & Hsu, 2015). Despite these deficits, and in contrast to adult learners in McGregor et al. (2017a, 2017b) who failed to improve over days, children with DLD and typically developing children in Bishop and Hsu continued improving across days.

Although these two lines of research appear at odds, the studies investigating learning and retention of a novel grapho-morpheme symbol (Adi-Japha et al., 2011; Adi-Japha & Abu-Asba, 2014) and sequential motor movements (Hedenius et al., 2011) engage the procedural memory system supporting implicit learning of sequential and probabilistic information (Squire & Zola-Morgan, 1996). This system recruits a brain network including subcortical (basal ganglia, cerebellum) and cortical brain regions (parietal, frontal, premotor cortex, and Broca's area) (Squire and Zola Morgan, 1996). Ullman (2004) proposed that impairments in DLD originate in deficits in the procedural learning system whereas an intact declarative learning system, involving the hippocampus, supports memory for explicitly learned word mappings (Squire and Zola Morgan, 1996; see also Sharon, Moscovitch, & Gilboa, 2011). For the most part, studies suggesting poor encoding but intact consolidation (e.g. Bishop & Hsu, 2015; McGregor et al., 2017a,b) involve word learning engaging declarative learning, whereas studies showing overnight and long-term loss (Adi-Japha et al., 2011; Adi-Japha & Abu-Asba, 2014; Hedenius et al., 2011) primarily tapped procedural learning. Given possible contributions of REM to integration of new language learning (Batterink et al., 2017; Tamminen et al., 2017), and sleep-dependent consolidation of procedural (Plihal & Born, 1997) and perceptual learning (Plihal & Born, 1999), it will be important to measure sleep EEG in learners with DLD.

However, questions remain regarding the group differences in memory for new speech sounds documented over a 24-hour delay by Earle et al. (2018) and over a period of a week in recall of word forms in an earlier study by McGregor et al. (2013), suggesting impaired consolidation in DLD. Close examination of the findings suggests that language-impaired adults are not forgetting. Rather, impaired learners do not improve after initial encoding compared to unimpaired learners, who do improve. Repeated exposure to and testing of trained stimuli at the later time points likely contributed to the improvements documented for the typical learners (McGregor et al., 2013), with additional opportunities for encoding and retrieval being known to improve memory (Bäuml et al., 2014; Roediger & Karpicke, 2006). Typical learners in McGregor et al. (2017a, 2017b) who did not experience additional opportunities for learning held steady but did not improve their retention after a delay.

Interestingly, compared to the impaired adult language learners in McGregor et al. (2013) who did not improve across additional opportunities for encoding and retrieval through retrieval practice, children with DLD improved across sessions as much as typically developing children (Bishop & Hsu, 2015). There are two possible explanations for this benefit. Children exhibit greater amounts of slow-wave activity than adults at 7–10 years (Ohayon et al., 2004; Campbell & Feinberg, 2009), a factor that may contribute to real-time processing of language, possibly contributing to children's continued improvement across days compared to adults (James et al., 2017; Wilhelm et al., 2013). However, neither study directly compared children and adults who are likely to differ in their encoding of novel language materials. Studies also varied in the number of trials required during encoding with adults obtaining many more encoding trials in McGregor et al. (2013, 12 exposures to 32 mappings) than children (Bishop & Hsu, 2015, 5 exposures to 8 mappings). Prior work shows little overnight benefit for overlearned sequential information (Kuriyama, Stickgold, & Walker, 2004) compared to lesser-learned information (Drosopoulos, Windau, Wagner, & Born, 2007; Kuriyama et al., 2004). As such, the increases in performance across days in children observed by Bishop and Hsu (2015) could stem from

differences in levels of initial encoding or from the higher levels of slow-wave activity in children's sleep, representing an avenue for future research.

In sum, although we still know little about the role of sleep in language impairment, the links between insufficient sleep and vocabulary outcomes in young children make investigations of sleep a priority for children diagnosed with DLD or at high risk of DLD by merit of having a close family member with this diagnosis. Given these links it will be important to educate parents of children diagnosed with DLD or at high risk of DLD about the need for and practices ensuring healthy, high-quality sleep. As noted earlier, restricting naps may help some preschool-age children better consolidate their nighttime sleep. However, given changes in children's sleep patterns in their transition out of napping, it will be important to have a better understanding of the relationship between naps, nighttime sleep, and brain maturation before applying sleep extension to children with DLD. A more fruitful practice would be to inform parents widely about methods of maximizing healthy sleep, given the overall importance of sleep for learning and development. Finally, given poor initial encoding in DLD and the fact that retrieval testing at a 2-hour delay interferes with word-form recognition compared to retrieval testing at a 12-hour delay after more complete consolidation (McGregor, 2014), sufficient sleep tailored to the requirements of the developmental period should also protect language learning from interference.

## Theories of sleep consolidation

We now discuss theories of sleep consolidation as a precursor to the following section where we propose that brain development may constrain memory formation, and hence language acquisition, differently across periods of early development.

Different phases of sleep appear to contribute differently to memory formation (Diekelmann & Born, 2010) with NREM contributing to consolidation of declarative memories and REM thought to contribute to integration of newly learned information into existing stores (Batterink, Westerberg, & Paller, 2017; Tamminen, Ralph, & Lewis, 2017) and possibly to certain forms of procedural memory (Plihal & Born, 1997). Many more studies contribute to understanding of the effects of NREM on memory, with much less known about REM. NREM factors centrally in several theories in the literature for understanding how sleep contributes to memory formation.

Active systems theory builds on the complementary learning systems view of memory consolidation, which proposes that the brain encodes new memories simultaneously in slow-learning cortical and fast-learning hippocampal stores, with the hippocampus acting as a trainer for integrating and strengthening memories in cortical stores (McClelland, McNaughton & O'Reilly, 1995). During sleep, brain oscillations of different frequencies are thought to coordinate and assist this process (Diekelmann & Born, 2010). Sharp-wave ripple activity consisting of transient, high-frequency sharp waves originating in the CA3 subfield of the hippocampus and ripples occurring in the CA1 subfield reflect replay of pre-sleep learning experience (Wilson & McNaughton, 1994). These high-frequency oscillations nest within slower ones in time such that sharp-wave ripples occur in conjunction with individual 12–17 Hz thalamo-cortico spindles, and spindles occur in conjunction with individual 0.5–4 Hz cortical slow oscillations (Mölle & Born, 2011). Together, spindle-ripple events aid in information transfer between the hippocampus and cortical regions (Mölle & Born, 2011). In support of this idea, associations between better memory performance and spindle activity (Fogel & Smith, 2011; Clemens et al., 2005; Friedrich et al., 2015, 2017; Kurdziel et al., 2013; Schabus et al., 2004; Smith et al., 2017;

Tamminen et al., 2010, 2013) and slow-wave activity (Holz et al., 2012; Daurat et al., 2007; Drosopoulos et al., 2004; Marshall et al., 2004; Simon et al., 2017) provide support for the idea that these oscillations contribute to sleep-dependent memory formation.

Evidence for active systems theory stems almost exclusively from studies of declarative learning, involving tasks that engage the hippocampus. This theory may not apply to sleep-dependent benefits in infant learning given underdevelopment of the circuitry in the CA3 subfield of the hippocampus supporting sharp-wave ripple replay and thus active systems consolidation in infants (see Gómez & Edgin, 2015).

Three other theories are agnostic regarding hippocampal involvement. According to a second theory of sleep consolidation, sleep downregulates energy that builds in the brain during the day, downscaling new synaptic connections so that the most potentiated synapses remain at the expense of weaker ones (Tononi & Cirelli, 2014). A third view finds evidence for a contribution of sleep to potentiation of new connections in the cortex in animals too young to have a fully developed hippocampus (Aton et al., 2013). Finally, neuromodulators in REM and NREM2 may act to destabilize existing connections, permitting the integration of new associations in the cortex (Poe, 2017).

Although sleep spindles correlate with markers of memory formation in 6- to 16-month-old infants (Friedrich et al., 2015, 2017), and low-frequency NREM activity (range 1–10 Hz) correlates with memory formation at 6 months (Simon et al., 2017), the trisynaptic circuit supporting sharp-wave ripple activity in the hippocampus and connections to the prefrontal cortex are underdeveloped at these ages (Lavanex & Banta Lavenex, 2013; Ngo et al., 2017), making it difficult to match oscillatory activity to a particular theory. Spindle activity could be a proxy for active systems consolidation or a marker of cortical reorganization, according to Poe (2017), representing an avenue for future research.

Next, we consider how brain development may constrain sleep-dependent memory formation and, in turn, language acquisition, and the theoretical considerations thereof.

## How brain development may constrain language acquisition differently at different points in early childhood

Although language acquisition benefits from extensive study, for practical reasons, much of what we know about language learning in very young children stems from testing retention in the seconds immediately after encoding of novel language structure in the case of statistical-learning studies, or word mappings in word-learning studies. But memory formation takes place over time with cellular, molecular, and systems-level processes unfolding over distinct phases of induction seconds after encoding, stabilization minutes later, consolidation hours after encoding, and maintenance a day or more later (Rudy, 2014). Given that subsequent phases of memory formation depend on earlier ones, we may mischaracterize the learning process if we use retention at the timescale of seconds as a proxy for learning. Additionally, the underlying learning system may dictate the fidelity of the trace hours later. According to Complementary Learning Systems Theory, the brain supports distinct learning networks (McClelland et al., 1995) with the cortex supporting gradual learning of novel associations and the hippocampus supporting rapid learning through replay of memories during sleep (Diekelmann & Born, 2010; Wilson & McNaughton, 1994). Gómez and Edgin (2015) predicted a more gradual process of cortical consolidation during infancy versus rapid strengthening and redistribution of hippocampal memories in hippocampal-cortical networks over 24 hours and sleep in toddlers (see Gómez, 2017, and Gómez & Edgin, 2016, for more detailed discussion of developmental brain changes).

At the present time, we lack a coherent picture of how children form long-term memories of new language structure before 36 months. This is a period of substantial brain development (Lavenex & Banta Lavenex, 2013) accompanied by increases between 24 and 43 months of behaviors in human children typically associated with hippocampal function (Newcombe et al., 2014; Olson & Newcombe, 2014; Ribordy et al., 2013); substantial development in the ability to encode new words (e.g. Bion et al., 2013); research in animals showing the emergence of coordinated sharp-wave ripple activity by the equivalent of about 8 months of age in humans (Buhl & Buzsáki, 2005) but underdeveloped default-mode activity before about 2 years of age, when it first shows intrinsic connectivity of the hippocampus with other memory systems (Gao et al., 2009); increased association between structural changes in the human hippocampus and growth in expressive vocabulary after this age (Lee et al., 2015); and continued extensive development in hippocampal connectivity to anterior and posterior brain regions between 4 and 10 years of age (Blankenship, Redcay, Dougherty, & Riggins, 2017).

Before 24 months, 15-month-old children remembered the most statistically reliable information in an artificial language corpus after a nap and a 4- or 24-hour delay, but not the less frequently experienced information (Gómez et al., 2006; Hupbach et al., 2009). In both experiments, infants retained knowledge that the first word in a string predicts the last word, but they applied this knowledge liberally. They listened longer for the remainder of the test to the set of strings they heard on their first test trial regardless of whether the strings came from their training language or from a language with a contrasting nonadjacent dependency relation. In contrast, infants listen longer on average to strings from their training language versus strings from the other language when tested immediately after training (Gómez & Maye, 2005). In particular, each string infants heard in the training corpus contained a consistent relationship between specific first and last words, with half of the strings manifesting one nonadjacent relation (e.g. vot-X-jic) and the other half a different one (e.g. pel-X-rud). The fact that infants listened longer across the test trials to strings heard on the first test trial after a delay containing sleep, even when the specific nonadjacent dependencies differed from training, suggests they forgot the specific details of the strings in favor of the most statistically reliable information in the corpus, that the first word in a string predicts the last. Such forgetting supports generalization, a particularly important form of learning (Gómez et al., 2006). After 24 months children show robust specificity in their memories after sleep (e.g. Williams & Horst, 2014).

Based partly on information like this and partly on what we know about hippocampal development in young non-human primates (Bachavalier, 2014; Lavenex & Banta Lavenex, 2013), Gómez and Edgin (2015) argued that cortical learning, available in infancy, predicts a gradual process of sleep-dependent memory formation. In contrast, late-developing connectivity between the hippocampus and other memory networks (Gao et al., 2009) predicts a rapid process of sleep-dependent consolidation at a later developmental time point. They proposed a fundamental change in memory formation after about 18–24 months that reflects increased development of key hippocampal regions and their circuitry, a prediction supported by animal analogues at comparative human and non-human primate ages (Bachavalier, 2014; Lavenex & Banta Lavenex, 2013). Prior to increased hippocampal maturity, sleep-dependent effects should result from more gradual processes involving synaptic downscaling (Tononi & Cirelli, 2014), cortical plasticity (Aton et al., 2013), or REM-dependent integration (Poe, 2017), processes that may decelerate the rate of forgetting versus a fast-acting process of hippocampal-supported active systems consolidation (Diekelmann & Born, 2010) that should come online with increased hippocampal maturation (Gómez & Edgin, 2015).

The implications for language learning are vast given that a learning system that forgets easily and thus learns slowly is less likely to get stuck in local minima, tuning instead to statistically

reliable information over information that is less reliably supported in language input (Gómez, 2017). Slow learning helps alleviate concerns that children will become stuck on a particular hypothesis, a concern raised by language theorists (Pinker, 1995), and supports the fine-grained tuning children must achieve of the complex correspondences among different phonetic, phonological, and morpho-phonological cues in language, putting children in an excellent position to maximize use of this slowly acquired knowledge once the brain supports more robust and rapid learning. At that point in development, the hippocampus may support rapid binding of information in different modalities, an ability that may factor crucially into word learning, where children must bind a label to a visual referent, as well as information about that referent stored in different modalities. We should also observe robust consolidation with sleep, and we do (see Sandoval et al., 2017; Werchan et al., 2016; Williams & Horst, 2014). Although word learning benefits from sleep in infancy (Friedrich et al., 2015, 2017; Horváth et al., 2015, 2016), children need many exposures (eight or more) to achieve encoding, with the need for repeated exposures a hallmark of some forms of cortical learning (McClelland et al., 1995; see also McClelland, 2013). Given the results of Gómez et al. (2006) and Hupbach et al. (2009), showing generalization to novel strings based on forgetting the specific words instantiating a pattern in an artificial language, we predict that infants in word-learning studies will show loss of detail in their memories if tested 24 hours later, as opposed to 1–2 hours later, whereas older children will show greater fidelity in their memories. Although 6-month-old infants show retention of new word mappings over a sleep delay, they show poor retention of new word learning 24 hours after encoding (Friedrich & Friederici, 2011). Consistent with the idea that the brain increases its ability to retain new word mappings over development, 3-month-olds show less mature neural signatures of learning and fail to retain learning the next day (Friedrich & Friederici, 2017). Another form of support for the idea that children engage cortical learning is the fact that although infants can retain memory for a single action over a 24-hour delay containing sleep (Seehagen et al., 2015), they do not retain briefly presented sequences of arbitrarily related actions over a 2-week delay until 28 months (Bauer et al., 1998). High-resolution brain imaging implicates the trisynaptic pathway of the hippocampus in rapid memory formation for sequential information (Hsieh et al., 2014; Schapiro et al., 2012), a pathway crucial to the support of long-term retention through sleep neural replay.

## Conclusions and open questions

In closing, we argue that sleep contributes crucially to language learning in early childhood. We see evidence of this in better retention of new language learning followed by a nap (Friedrich et al., 2015, 2017; Gómez et al., 2006; Horváth et al., 2015, 2016; Hupbach et al., 2009; Sandoval et al., 2017; Werchan et al., 2016; Williams & Horst, 2014) or nighttime sleep (Henderson et al., 2012, 2013, 2015; Smith et al., 2017). We also see a sleep benefit in longitudinal work investigating associations between a minimum level of nighttime sleep quantity and later vocabulary outcomes (Touchette et al., 2007) and earlier developmental consolidation of nighttime sleep and later vocabulary (Bernier et al., 2010; Dionne et al., 2011). We also provide evidence suggesting the importance of investigating the effects of sleep in populations at risk of language impairment (e.g. Bishop & Hsu, 2015; Earle et al., 2018; McGregor, 2013; McGregor et al., 2017a, 2017b). Finally, the contributions of brain development to sleep consolidation may affect the nature of language learning differently in early and later development (Gómez & Edgin, 2015), providing unique advantages for the kind of perceptual learning children must engage in early on in tuning to the vast details of their native language (Gómez, 2017) as compared to

the rapid binding of object labels to their meanings that children exhibit later in development in conjunction with the word spurt (Goldfield & Reznick, 1990).

We close our review of sleep and language with several open questions. One question has to do with the interrelationship of language environment and sleep. Studies investigating the relationship between sleep duration and nighttime sleep consolidation in early childhood and vocabulary outcomes do not typically factor in language input. Yet children hearing more language have larger vocabularies at age 3 years (Hart & Risley, 1995). Related to this issue, perhaps children with a larger language base will depend less on naps for aiding consolidation at earlier ages. Behavioral findings and computational modeling provide reason to think that learners might incorporate new learning immediately into cortical networks with sufficient background knowledge (McClelland, 2013). Parental responsiveness also contributes to language learning (Goldstein & Schwade, 2008; Tamis-LeMonda, Bornstein, & Baumwell, 2001). Either language input or parental responsiveness may thus offer protection for children with poor sleep. Such factors may also correlate with parenting qualities that may contribute to aiding children in achieving developmentally earlier sleep consolidation, such as practices for ensuring consistent, high-quality sleep.

A second question has to do with what sleep physiology may indicate in infancy given underdeveloped mechanisms for supporting active systems consolidation. Without the ability to conduct high-resolution imaging or intracranial recordings during real-time memory encoding, sleep, and memory retrieval, we cannot gauge hippocampal involvement in memory formation in human infants. Using the same statistical-learning or word-learning tasks with infants across a period of maturation of the hippocampus (e.g. 12–30 months) would provide useful, if imperfect, information about the learning systems involved. In particular, we predict robust consolidation with sleep once hippocampal development is mature enough to support active systems consolidation. Before that point in development, sleep may provide some benefit for stabilizing the most statistically reliable information from the input while permitting forgetting of the less reliable or idiosyncratic information (Gómez & Edgin, 2015). Evidence that infants do not retain word learning over 24-hour delays at 3 and 6 months accords with this hypothesis (Friedrich & Friederici, 2011, 2017), but data are missing for addressing this hypothesis in older infants.

Finally, it will be important to obtain more precise understanding of the interplay of daytime and nighttime sleep and its contributions to brain development and language learning across the early years of development. Such understanding will further inform parents and practitioners about best practices for achieving healthy sleep in young children. Research on the transition away from habitual napping also has important policy implications when it comes to preschool-classroom planning given tradeoffs educators may perceive in replacing mandatory naptimes with instructional time. In cases of mandatory napping, such as Australia, where children have mandatory naptimes until they enter school at age 6, children who napped on average longer than 60 minutes had less nighttime sleep than children napping less than 60 minutes. Furthermore, longer nappers continued to sleep less at night at a second time point when they were in school and no longer napping habitually, suggesting possible long-term impacts on sleep (Staton et al., 2015). Although duration of daytime naps varies widely by culture across ages 3–5 years, children experience similar amounts of total sleep time in a 24-hour period regardless of culture (Mindell, Sadeh, Kwon & Goh, 2013). Given that shorter nighttime sleep associates with lower vocabulary outcomes (Touchette et al., 2013), it will be crucial to better understand optimal ratios of daytime to nighttime sleep across different stages of early development.

In conclusion, sleep contributes over the long term to the inventory of information children accumulate in acquiring their native language. Sleep may also interact with developing brain structures to maximize learning across early development (Gómez, 2017; Gómez & Edgin, 2015, 2016). When learners need to build up their knowledge of language conservatively, through a process ensuring retention of the most reliable and consistent information in complex input and forgetting of less reliable information, sleep aids in this process. Once children amass a significant amount of language information, the maturing brain can further support learning through rapid binding of information from multiple modalities and robust sleep consolidation. Such differences in early and late memory formation may contribute to the differences we see in infant and adult learners of a second language (Gómez, 2017). Poor sleep may also be an understudied factor contributing to poor language outcomes (Dionne et al., 2011; Earle et al., 2018).

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## SECTION 2

# Dimensions of language learning



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# 9

# SPEECH PERCEPTION AND DISCRIMINATION

## From sounds to words

*Caroline Junge, Natalie Boll-Avetisyan, and Titia Benders*

Most children listen to speech as their primary source of communication. Yet which language they learn depends on where they grow up (Cutler, 2012): for instance, babies growing up in the Netherlands will grow up speaking Dutch while those growing up in China might master Mandarin, or Cantonese. All these languages are markedly different: they differ in the repertoire of speech sounds, in the use of suprasegmental information (whether acoustic variations above the level of phonetics/phonemes, such as word stress and tone, can differentiate between words), and in phonotactic information (which phoneme combinations are permissible in a language or not). When infants are born, their natural preferences and abilities in speech perception are hardly shaped by their native language. In other words, newborns are considered "universal listeners" (Kuhl et al., 2008). Yet through repeated exposure to their native language, cross-linguistic differences between infants soon become apparent, which suggests that the first year of life sets the scene for language-specific listening. This chapter makes clear that speech perception is not a trivial task: speech is like a stream of sounds embedded in words combining into phrases, with no pauses that reliably signal where words begin or end (see Figure 9.1). Fortunately, speech contains and conveys cues to many linguistic elements simultaneously. Speech perception is the process of extracting cues from the speech stream, to recognize the message that a speaker is conveying. This process is further complicated by the fact that all speakers are different and therefore produce the cues slightly differently. In what follows next, we will first describe the input that children are exposed to (Section: What kind of speech do children hear?), before we turn to how children learn to recognize their native language from other acoustic signals (Section: How do children recognize their language?) and to decompose it into meaningful units: into sounds (Section: How do children recognize native speech sounds?), into suprasegmental units (Section: How do children acquire prosodic knowledge?), and finally, into words (Section: How do children recognize words in speech?). Then we discuss the development of speech perception in relation to speech exposure and brain maturation (Section: Speech input and brain maturation). In our concluding section (Concluding remarks and future directions) we underscore the relevance of early speech perception skill as crucial for language acquisition.

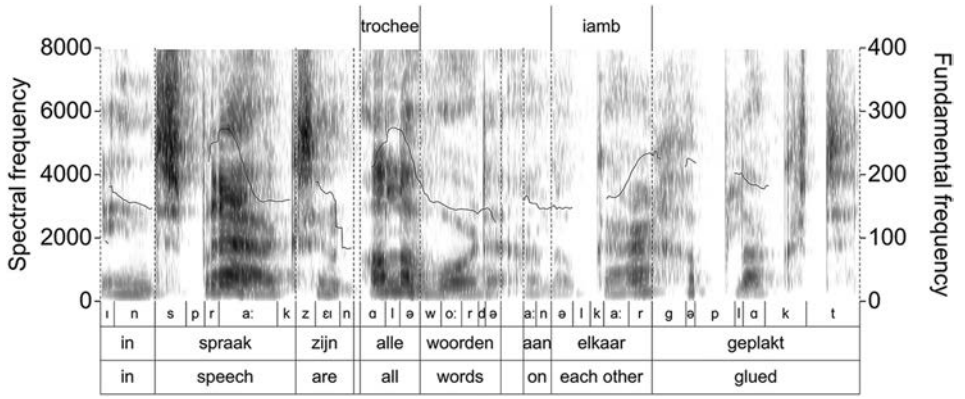



*Figure 9.1* A figure to illustrate that speech is a continuous stream of sounds: a sound spectrogram of a Dutch utterance "in speech, all words are glued together", with time on the x-axis, spectral frequencies from 0 to 8000Hz (cues to vowel and consonant properties) on the left y-axis, and fundamental frequency (a cue to intonation and word stress, indicated by means of the superimposed rising and falling line in the spectrogram) on the right y-axis. The tiers below the spectrogram show the speech stream segmented into relevant subunits of speech: the top tier displays segments. The second tier groups these segments into Dutch words. Note that pauses in the speech signal the onset of voiceless plosives (/k/, /p/, /t/); they do not align with the onset or offset of words. The third tier offers a translation of the words into English.

## What kind of speech do children hear?

The primary source of speech is vocal fold vibration, resulting in voiced sounds with a fundamental frequency, which is perceived as pitch. Speech can also vary in amplitude, perceived as loudness fluctuations, and in the duration of segments and phrases, which may signal speaking rate, among many other things. Pitch, amplitude, and duration are all essential cues to suprasegmental structure, such as lexical stress, tone, and intonation (e.g., Fry, 1955; Pierrehumbert, 1980). To exemplify how stressed and unstressed syllables differ: compare in Figure 9.1 the syllables in the disyllabic words /ɑlə/ "all" and /ələkaːr/ "each other". The first syllable in /ɑlə/ and the second syllable in /ələkaːr/ carry lexical stress, as signaled by their being higher in pitch, louder, and longer than the other syllable.

Most notably, however, speech consists of segmental information, that is, different consonants and vowels. Suprasegmental cues also play a role in distinguishing between these main segmental classes: vowels are typically voiced, and are louder and longer than consonants. Further differentiation within these classes primarily draws from cues such as spectral information attenuated by the shape of the vocal tract (Fant, 1960). More specifically, the resonance in the vocal tract creates formant frequencies for voiced sounds and bands of noise energy in voiceless sounds.

The primary cues to differentiate between vowels are the first and second formant frequencies, which are generally carried by spectral frequencies between 100 and 3000Hz (Peterson & Barney, 1952). Other cues are the consonant-vowel formant transitions and cues such as duration and fundamental frequency (for a review see Rosner & Pickering, 1994). The primary cues to consonants are less easy to pinpoint, as consonants can be either voiced or voiceless, and their cues are temporally distributed across the speech stream. For example, to recognize [k] in Dutch /ələkaːr/, a listener needs to recognize a brief moment of silence after the [l], followed by a burst. Despite the lack of formant frequencies in most consonants, consonant identification also relies critically on spectral information, including the spectral energy of the burst (at frequencies that

can go up to 10,000Hz), and the transitions of formant frequencies into the following vowel (see for a survey of cues Repp, 1982; Wright, 2004).

Children begin "training" to become expert native-language perceivers as 24-week-old fetuses, when their auditory system begins functioning (DiPietro et al., 2013). Most sounds are transmitted to the fetus through the tissue and fluid of the womb, which attenuates frequencies over approximately 500Hz and strongly attenuates frequencies over 1000Hz (Querleu et al., 1988). The suprasegmental cues are thus somewhat audible to the fetus, whereas cues to vowels and consonants are much less audible or not at all (although describing the womb as a low-pass filter may be too simplistic; see Lecanuet et al., 1998). Before birth, infants are thus exposed to the suprasegmental aspects of their native language, as well as to some segmental cues (Querleu et al., 1988).

At birth, infants are for the first time exposed to speech transmitted through air with unattenuated spectral frequencies. In addition, they hear a special register, as adults tend to speak to infants with so-called infant-directed speech (IDS). Suprasegmental cues, in particular fundamental frequency, are strongly modulated in IDS with a high pitch, a large pitch range, and possibly a slower speaking rate (see for reviews Ferguson, 1977; Soderstrom, 2007; cf. Martin et al., 2016). Also, the segmental contrasts appear to be changed in IDS, although there is debate whether the spectral cues to vowel contrasts are enhanced in IDS compared to adult-directed speech (ADS; e.g., Kuhl et al., 1997; Tang, Rattanasone, Yuen, & Demuth, 2017), or, conversely, may be reduced (Benders, 2013; Englund & Behne, 2005; Martin et al., 2015). Similarly, some studies suggest that temporal cues to consonant contrasts are enhanced in IDS (e.g., Malsheen, 1980; Fish, García-Sierra, Ramírez-Esparza, & Kuhl, 2017), whereas others find that these apparent enhancements may be side effects of the IDS prosody (McMurray, Kovack-Lesh, Goodwin, & McEchron, 2013) or entirely absent or reversed (e.g., Baran, Laufer, & Daniloff, 1977; Narayan, 2013).

Regardless of the precise differences between the two registers, we do know that infants treat them differently: infants prefer listening to IDS over ADS (Cooper & Aslin, 1990; Fernald, 1985), possibly because of its emotional valence and/or arousal (Singh, Morgan, & Best, 2002). Because of its special properties, IDS has been suggested to be an ideal source for children to discover their native language's prosody, contrastive speech sounds, and words (Liu, Kuhl, & Tsao, 2003; Nelson, Hirsh-Pasek, Jusczyk, & Cassidy, 1989; Ramírez-Esparza, García-Sierra, & Kuhl, 2014; Thiessen, Hill, & Saffran, 2005).

## How do children recognize their language?

In order to initiate language acquisition, before everything, the infant needs to be able to separate language in the acoustic environment from non-speech input. This may already be a non-trivial task. Could it be that infants are intrinsically biased to listen to speech? If so, is this bias triggered by specific aspects of speech that facilitate language recognition and help to initiate language acquisition? Which are a language's properties that infants can use to recognize speech as language, maybe even as *their* language? Such questions have been the focus of studies with newborns, which highlights that neonates already have elaborate speech perception abilities.

To explore whether infants differentiate between speech and non-speech acoustic signals, it is necessary that the type of non-speech signal compared to speech is of similar acoustic complexity, so that it cannot be claimed that speech is simply more interesting. Controlling for acoustic complexity, studies have found that newborns prefer human speech over non-speech analogues, whether this be sinusoidal speech (Vouloumanos & Werker, 2007) or music (Dehaene-Lambertz et al., 2010). Such results provide a strong indication that from birth infants are biased to listen

to speech. Moreover, the left hemisphere already appears dominant for language processing (see also Chapter 2, this volume): newborns show greater left hemispheric brain activity when listening to forward speech compared to backward speech (Peña et al., 2003), or compared to other non-speech sounds (emotional voices, monkey calls, scrambled speech; Minagawa-Kawai et al., 2011) – an effect that persists until older age (e.g., Dehaene-Lambertz, Dehaene, & Hertz-Pannier, 2002).

Infants' initial perception abilities are, probably as a result of prenatal experience (see Section: What kind of speech do children hear?), even more specialized than discriminating speech from non-speech. It appears that newborns are already sensitive to the rhythm of their language, as they can discriminate between rhythmically distinct languages (Mehler et al., 1988), that is, between stress-timed languages such as English and syllable-timed languages such as French (cf. Cutler, 2012; see also Chapter 16, this volume). Moreover, they show greater left hemisphere activation when processing their native language compared to an unfamiliar one with a different rhythm (Minagawa-Kawai et al., 2011). Furthermore, when listening to two unfamiliar languages, they prefer the one whose rhythm resembles that of their native language (Mehler et al., 1988). This suggests that infant speech perception initially is focused on prosodic information, as evidenced by similar effects when newborns are exposed to low-pass-filtered speech (Nazzi, Bertoncini, & Mehler, 1998). Also, infants remain unable to discriminate between languages of comparable speech rhythm until the age of four months (Bosch & Sebastián-Gallés, 1997; Mehler et al., 1988).

As described above (Section: What kind of speech do children hear?), infants' prenatal experience with speech is largely limited to its suprasegmental information, as segmental information is not so well transmitted. Hence, it is likely that prosody is a characteristic of speech that catches infants' special attention from the start (Gleitman & Wanner, 1982). Newborns' preferences for forward over backward speech may also point towards their preference for their native language's speech rhythm. Forward and backward speech are of comparable physical complexity and share many acoustic characteristics, in particular with regards to its segmental properties (i.e., fricatives, nasals, and vowels sound similar when they are reversed, as their formant structures are relatively symmetrical around their nucleus). Differences between the signals should be most notable in their rhythmic structure (e.g., across languages, speech typically displays a steady decrease in pitch over the envelope of a sentence, and final syllables are lengthened – properties that are reversed in backward speech). Indeed, neonates can only discriminate between two rhythmically distinct languages when speech is played forward but not backward (Mehler et al., 1988; Ramus, Hauser, Miller, Morris, & Mehler, 2000).

However, prosody cannot be the exclusive feature of language that infants are attending to. The type of segmental information also appears to direct attention. For example, sinusoidal speech (as used in Vouloumanos & Werker, 2007) only removes most segmental information but preserves prosodic properties like duration relationships between units, pitch contours, and amplitude envelopes; still, neonates show a clear preference for natural speech. Moreover, May, Gervain, Carreiras, and Werker (2017) found that newborns showed greater activation in areas related to language processing when perceiving two spoken languages (English and Spanish) compared to perceiving a whistled language (Silbo Gomero). Interestingly, the latter language patterns like Spanish regarding its prosodic and rhythmic structure; the main acoustic difference is that Silbo Gomero has acoustically simple whistled tones instead of spectrally complex phonemes.

Future studies should explore in more detail what the properties of language are that neonates are attracted to. By disentangling the role of acoustic complexity and the rhythmic and maybe even segmental characteristics of the native language, we will get a better understanding of how infants learn to recognize their language, distinguishing it from other acoustic signals.

## How do children recognize native speech sounds?

The first step to native-language speech perception is perceptual attunement: learning to discriminate better between two segments that one's native language maps onto two different segment categories than between sounds that the language maps onto a single category (Aslin & Pisoni, 1980). Emerging evidence suggests that newborns respond differently to native than non-native vowels and have thus acquired some aspects of native segment perception prenatally (Moon, Lagercrantz, & Kuhl, 2013). However, the received accounts of perceptual attunement still describe the newborn as a "universal listener" (Kuhl et al., 2008). The universally listening newborn discriminates well between some speech sound contrasts and more poorly between some other contrasts, and exposure to the full speech spectrum as transmitted through air will enable her or him to perceptually attune to her or his native language.

The pathways of perceptual attunement differ between sound contrasts, depending on children's (in)ability to discriminate the contrast at birth, and the status of the contrast in their native language. Some consonant contrasts are discriminated well at birth, and that ability is *maintained* if the contrast is phonemic in the native language, and *lost* if it is not phonemic. A seminal example is the contrast between velar [k] and uvular [q], discrimination of which is *maintained* by Salish-learning infants and *lost* by English-learning 10-to-12-month-olds (Werker & Tees, 1984). Other consonant contrasts are not discriminated well at birth, and discrimination is *facilitated* (i.e., shows improvement) if the contrast is phonemic in the children's language (Kuhl, Conboy, Padden, Nelson, & Pruitt, 2005; Tsao, Liu, & Kuhl, 2006), but *remains undeveloped* if the contrast is not contrastive. To illustrate, take the contrast between alveolar [n] and velar [ŋ] in onset position: discrimination is *facilitated* for Filipino 10-to-12-month-olds, but *remains undeveloped* in English infants (Narayan, Werker, & Beddor, 2010). Exceptions to perceptual attunement occur if infants maintain full sensitivity to a contrast that is not phonemic in their native language, such as the discrimination between Zulu clicks by infants exposed to English (Best, McRoberts, & Sithole, 1988).

Infants do not become perceptually attuned only to consonant contrasts, but also to vowel contrasts. For example, English infants may *lose* their initial ability to discriminate between [y] and [u] after six months' listening experience, an ability that is still present in four-month-olds (Polka & Werker, 1994). An apparent difference between perceptual attunement to consonants and vowels is that full loss may not occur, and all vowel contrasts may remain (to some extent) discriminable by all infants (Tsuji & Cristia, 2014). Discrimination within, rather than between, vowel categories has frequently been studied in the context of the perceptual-magnet effect, which describes that human adults and six-month-old infants (but not monkeys) have more difficulties detecting changes around "good" vowel examples compared to changes around "poor" vowel examples (Kuhl, 1991). Six-month-old infants may only display this perceptual-magnet effect around the good examples of native, but not non-native vowels (Kuhl, Williams, Lacerda, Stevens, & Lindblom, 1992). Although perceptual attunement primarily refers to discrimination between sounds that belong to different vowel categories, whereas the perceptual-magnet effect describes gradient discrimination within a vowel category, both describe that infants typically learn not to discriminate between sounds that their language maps unambiguously onto one single category.

What determines the exact attunement pattern for a contrast within a language? The initial state of attunement can be related to acoustic salience: infants appear better at discriminating between salient than non-salient contrasts (Eilers, Wilson, & Moore, 1977; Narayan et al., 2010). Acoustic salience may also account for the end state of attunement, as it might explain why adults maintain sensitivity to some non-native contrasts (Repp, 1984). The rate of attunement

can be related to the frequency of segments in the infants' environment, with contrasts between frequent consonants being acquired before those involving infrequent consonants (Anderson, Morgan, & White, 2003). In addition, it is currently debated whether attunement is primarily driven by exposure to speech, or also shaped by word knowledge (Feldman, Griffiths, Goldwater, & Morgan, 2013; Swingley, 2009; Werker & Curtin, 2005) or social context (Conboy, Brooks, Meltzoff, & Kuhl, 2015; Kuhl, Tsao, & Liu, 2003).

Discrimination between speech sounds has so far been described as a symmetrical behavior, being equally strong from one member of the contrast to the other as vice versa. However, asymmetrical discrimination may also exist. For example, infants are able to discriminate a change from labial consonants (such as [p]) to coronals (such as [t]), but not vice versa (Dijkstra & Fikkert, 2011; Tsuji, Mazuka, Cristia, & Fikkert, 2015). As discrimination is better in the direction of the more salient and frequent coronals, saliency and frequency effects may both play a role in the existence or development of asymmetrical perceptual behavior. Asymmetrical discrimination also exists between vowel categories, as described by the native referent vowel framework (Polka & Bohn, 2011): universal listeners, at the outset of language acquisition, are good at discriminating spectral changes in the direction of salient vowel sounds that serve as natural referents, but not in the opposite direction. Later in development, these asymmetries may be attenuated by the category frequencies (Pons, Abareda-Catellot, & Sebastian-Galles, 2012). Ultimately, native speech perception requires the acquisition of symmetrical discrimination between phonemically contrastive speech sounds. Adult speech perception is then characterized by an acute sensitivity to cue changes that signal a native phonemic contrast, and by steep categorical boundaries between the sounds along an acoustic continuum that are perceived as one versus the other category (Liberman, Safford Harris, Hoffman, & Griffith, 1957).

## How do children acquire prosodic knowledge?

Across languages, words are typically characterized not only by their phoneme inventories and their phonotactics, but also by their prosody, that is, by suprasegmental characteristics. There are three different types of prosodic phenomena that characterize words: lexical stress, lexical tone, and lexical pitch accent. The acquisition of language-specific word-level prosody is an important milestone in language development, as it gives cues to speech segmentation and lexical acquisition (see Section: How do children recognize words in speech?). Regarding prosody acquisition, similar developmental trajectories can be observed as in the acquisition of sounds (see Section: How do children recognize native speech sounds?): usually it is observed that infants are relatively good at discriminating between prosodic patterns at birth, and that ability is *maintained* (and possibly improved) if they are contrastive in the native language, and *lost* if they are not.

### *Lexical stress*

Not all languages have lexical stress (e.g., French and Korean do without), but if they do, lexical stress comes in different forms. Some languages have fixed lexical stress, where acoustic prominence has to fall always on one specific position in the word (e.g., the first syllable in Finnish, the second-last syllable in Polish). Fixed stress is assumed to have a demarcative function that serves speech segmentation (Trubetzkoy, 1939/1969). Other languages have variable lexical stress (e.g., German, English, Spanish), where stress does not always occur in the same position of a word. In such languages, stress position can change the meaning (e.g., in German, TEnor means "common sense", while teNOR refers to a singer) or the syntactic class of a word (e.g., in English, /IMport/ is a noun while /imPORT/ is a verb; in Spanish, /FAbrica/ is a noun, "factory", while

faBRIca is a verb conjugated in the third person present tense). Consequently, in these languages stress has a contrastive function relevant for word recognition.

Several studies have indicated that infants are able to discriminate between different lexical stress patterns from birth (e.g., Sansavini, Bertoncini, & Giovanelli, 1997). Also French-learning infants are able to discriminate between lexical stress patterns at four months (e.g., Höhle, Bijeljac-Babic, Herold, Weissenborn, & Nazzi, 2009), which suggests that the discrimination ability for lexical stress patterns begins language-independently. However, by nine months, studies found French-learning infants' sensitivity to lexical stress to decline, which indicates effects of language-specific reorganization (Bijeljac-Babic, Serres, Höhle, & Nazzi, 2012; Skoruppa et al., 2009).

A characteristic of a variable lexical stress language is that prominence can occur on practically any position in a word, but usually some stress patterns are more frequent than others. In Germanic languages like Dutch, most bisyllabic words are trochaic (that is, they have stress on the first syllable), whereas it is much rarer for bisyllabic words to be iambic (that is, with stress on the final syllable). (Recall that Figure 9.1 actually depicts both types of bisyllabic words: the trochaic word /ɑlə/ "all" and the iambic word /əlkaːr/ "each other".) That infants are sensitive to this type of prosodic regularities in their language was revealed by studies that found that infants listened longer to trochaic than to iambic bisyllables, if in their native language the trochee is the predominant stress pattern (German-learning six-month-olds: Höhle et al., 2009; English-learning nine-month-olds: Jusczyk, Cutler, & Redanz, 1993), but show the opposite preference if the iambic pattern is predominant in their language (Hebrew-learning nine-month-olds: Segal & Kishon-Rabin, 2012), and show no preference if their language has no lexical stress (French-learning six-month-olds: Höhle et al., 2009).

In summary, present research suggests that lexical stress is subject to perceptual attunement in infancy, manifested in a decrease of sensitivity to lexical stress contrasts in infants learning a language without lexical stress, and an acquisition of language-specific knowledge of lexical stress. Future research should expand the study of lexical stress perception to infants learning languages with fixed lexical stress.

## *Lexical tone*

Not all languages have lexical tone (e.g., English and German do without), but if they do, its syllables carry contrastive pitch contour characteristics (e.g., rising, falling, flat) that point to different word meanings (e.g., in Mandarin, /ma/ can mean "mother", "hemp", "horse", or "scold" depending on the tone) or different grammatical forms (e.g., in Roermond Limburgian, a Dutch dialect, the word /kniːn/, meaning "rabbit", can be either singular or plural depending on the tone). Initial evidence suggested that lexical tone acquisition is also subject to perceptual tuning, just like phoneme and prosody acquisition. Mattock and Burnham's (2006) seminal study demonstrated a decrease in sensitivity to non-native tone contrasts (i.e., contrastive in Thai but not Chinese) by English-learning but not Chinese-learning infants at nine months, while at six months both groups could discriminate the tone contrasts (for similar findings, see Yeung, Chen, & Werker, 2013).

Newer research on the development of lexical tone sensitivity, however, suggests a more complex picture. It turns out that some tone contrasts are relatively salient and can be perceived even by infants for whom the contrast is non-native (e.g., Liu & Kager, 2014; Ramachers, Brouwer, & Fikkert, 2018), while, on the other hand, the discrimination of less salient contrasts can remain effortful even for older (up to 24-month-old) infants for whom the contrast is native (Cheng & Lee, 2018; Fan, Li, & Chen, 2018). On top of this, there are cases in which infants'

perception of non-native contrasts can even *increase* with infants' growing age (Chen & Kager, 2016; Chen, Stevens, & Kager, 2017), which possibly stems from infants' need to be sensitive to tonal contrasts at other levels than the segmental level (i.e., to detect intonation at the phrase or sentence level). Future research will need to disentangle the contribution of acoustic salience, language experience, and the relevance of tone at the sentence level in infants' perception of lexical tone.

### *Lexical pitch*

Not all languages have lexical pitch accent (e.g., French and English go without), but in languages that do have it (e.g., Japanese), the presence or absence of a pitch accent (marked by a steep pitch movement, e.g., a pitch fall in Japanese) and its location can change the meaning of a word (e.g., in Japanese, /HAshi/ with falling contour and pitch accent on /HA/ means "chopsticks", whereas /haSHI/ with rising contour and no pitch accent means "bridge"). Currently, hardly anything is known about the acquisition of lexical pitch accent. We know that newborns discriminate between lexical pitch accents (Nazzi, Floccia, & Bertoncini, 1998). One further study (Sato, Sogabe, & Mazuka, 2010) has investigated the perception of lexical pitch accent in infants acquiring Japanese, with the expected result that both four- and 10-month-olds discriminate between pitch accents. Evidently, more research is needed that includes infants acquiring languages without lexical pitch accent.

## How do children recognize words in speech?

Most of the words that infants hear occur within continuous speech (e.g., van de Weijer, 1998), while – as we have seen in Figure 9.1 – continuous speech does not provide clear silences between words to signal word boundaries. Although the evidence that input predominantly comprises multiword utterances comes from Germanic languages, the general assumption is that infants of any language are confronted with the *speech segmentation problem*: in order to learn words from the input, infants are required to segment the speech stream into word-like units. Yet languages differ widely in what they consider word-like units. In some languages, like Mandarin, all words are morphologically simple, while in agglutinative languages like Turkish, words are composed more complexly (i.e., structured around a word stem plus multiple possible suffixes). Therefore, infants should have formed a notion about typical word patterns in their native language before they can apply this knowledge to start extracting words from running speech. This presents us with a riddle, given that most of these words are presented in multiword utterances: how then do infants learn what words are?

There are two likely scenarios. First, it is possible that infants initially zoom in on those parts in the input that robustly highlight the typical shapes of words: that is, isolated words and, to a lesser extent, words at the edges of utterances. This is the top-down view. Although words in isolation surely do not occur frequently enough to be the sole explanation for vocabulary construction, they might occur sufficiently to build a rudimentary idea of how words pattern (Lew-Williams, Pelucchi, & Saffran, 2011). Words at phrase boundaries also prove informative, since here silence demarcates at least one of the word boundaries (Seidl & Johnson, 2006). Evidence that isolated words signal structure comes from experiments that show that the type of regularities within a set of isolated words of an artificial language subsequently shapes how infants segment a stream of words from that language (Thiessen & Erickson, 2012; Thiessen, Kronstein, & Hufnagle, 2013). Second, recognizing how words pattern could also be acquired through sensitivity to the distributional structure of the speech input (see also Chapter 4, this

volume). This bottom-up view assumes that infants can track which combinations of elements (e.g., sounds, syllables) often occur together, which indicates that these combinations are likely to be part of the same word. For instance, while the syllable "fol" is often followed by the syllable "low" as in "follow", or by "ly" as in "folly", a syllable like /is/ can occur with so many possible syllables that it shows it is not part of a word but stands alone. This view was first put forward by Saffran, Aslin, and Newport (1996) as a way to find multi-syllabic words in speech. This seminal study demonstrated that when infants were presented with an artificial language composed of four trisyllabic words, they grouped syllables together based on which combinations always appeared successively. Of course, this requires sensitivity to the unit of syllables, which infants appear to have by at least two months (Bertoncini & Mehler, 1981).

Besides sensitivity to statistical regularities, infants also appear to be born with certain universal linguistic biases that further help them discern which combinations are permissible in their native language (Berent, 2013). As said in the beginning, languages differ widely in their phonotactics. Most languages allow syllables to begin with consonant clusters, although certain clusters are more preferred than others (e.g., /bl/ to /lb/; the sonority sequence principle, Clements, 1990). Other languages are stricter: Korean lacks any type of onset consonant clusters. Yet despite the absence of consonant combinations, Korean adult speakers show the same kind of biases when judging nonwords with consonant clusters: they make fewer errors for consonant combinations that frequently occur in other languages than for those that are infrequent (Berent, Lennertz, Jun, Moreno, & Smolensky, 2008). Strikingly, even newborns show this phonological bias for onset clusters (Gómez et al., 2014).

At the level of prosody, the iambic-trochaic law is another example of a universal prosodic grouping bias (e.g., Hayes, 1995; Nespor et al., 2008). Recall that lexical stress is usually defined in three aspects: pitch, intensity, and duration. This law predicts uniformity in when and why humans group pairs of weak and strong syllables into a certain pattern, either as weak-strong (iambic) or as strong-weak (trochaic). When the more dominant cue is duration, this law predicts an iambic bias, whereas dominance in pitch or intensity leads to a trochaic bias. Infants also display this grouping bias (Bion, Benavides-Varela, & Nespor, 2011), regardless of whether lexical stress in their native language is fixed or variable (Abboub, Boll-Avetisyan, Bhatara, Höhle, & Nazzi, 2016). Again, this bias appears already present at birth (Abboub, Nazzi, & Gervain, 2016).

By examining parallels in the phonotactic rules of various natural languages, recent research is now revealing the existence of other phonotactic biases, and examining whether these are universal or emerge over development. Take, for instance, the labial-coronal bias (e.g., MacNeilage, Davis, Kinney, & Matyear, 1999): most languages (but not Japanese) prefer syllables with labials in the onset and coronals in coda-position rather than the reverse (e.g., /bat/ vs. /tab/). This bias appears universal as even Japanese infants at first display the same preference as French infants; only by 13 months is this preference reversed, and starts to mirror the phonotactic patterns of the infants' native language (Gonzalez-Gomez, Hayashi, Tsuji, Mazuka, & Nazzi, 2014). Clearly, infants come into the world equipped with certain prosodic and phonotactic biases that facilitates the building of word templates. Once infants have stored some possible words, the next step would then be to generalize across multiple possible words to learn about the permissible sound patterns in this language (that is, to acquire language-specific phonotactic and prosodic regularities).

Computational modeling studies offer additional support for the claim that infants can acquire knowledge of typical word patterns from bottom-up information. Computational models allow one to test which words computational learners find permissible, while directly controlling the type of input they are fed and the underlying learning mechanisms they have. By simply tracking the co-occurrences between syllables coupled with a sensitivity to word stress,

computational learners that receive input from real speech corpora (e.g., Dutch, American-English) can indeed acquire the phonotactic and prosodic regularities of these languages (Brent & Cartwright, 1996; Swingley, 2005). These computational results mirror experimental findings that show that American-English infants initially expect stressed syllables to always signal word onsets (e.g., Jusczyk, Houston, & Newsome, 1999) and can use phonotactic probabilities for speech segmentation (e.g., Mattys & Jusczyk, 2001a). Of course, both views (top-down and bottom-up) do not need to exclude each other. It is probable that infants employ both approaches to advance their lexical acquisition.

This sets the stage for the next question: how do infants extract words from speech? The speech stream is usually full of cues to signal word onset, from top-down cues, i.e., contextual cues and the lexicon, to more bottom-up cues, like word stress and phonotactics. Although most cues often work in concord with each other, there are plenty of ambiguous cases in which cues are conflicting. For example, the segment /s/ in the Dutch segment sequence /eːnspeːr/ can either belong to the preceding word /eːns/, followed by /peːr/ (meaning "once pear") or to the upcoming word /speːr/ (with /eːn/ /speːr/ meaning "one spear").

There is not one cue that appears to be foolproof in signaling word boundaries (Cutler, 2012). Research on adults has shown that cues are valued hierarchically, with adults favoring top-down cues over bottom-up, suprasegmental cues (Mattys, White, & Melhorn, 2005). But does this hierarchy also hold for beginning infant learners? It is likely that this is not the case, but that the hierarchy of cues develops over time. First, top-down lexical cues are expected to play a minor role for a long time; after all, infants' lexicons are still too small to make lexical cues very viable, even though there is evidence that infants as young as six months can use offsets of frequent words such as "mommy" to learn new words (Bortfeld, Morgan, Golinkoff, & Rathbun, 2005). Instead, it is more likely that infants begin mastering their speech segmentation skill by relying predominantly on bottom-up cues. Yet even at the level of bottom-up cues, there are multiple cues that shift in dominance over time. To illustrate, while one of the first dominant cues that infants can use is the language-general cue of the transitional probability between syllables (Kudo, Nonaka, Mizuno, Mizuno, & Okanoya, 2011; Thiessen & Saffran, 2003; see also Chapter 4, this volume), it appears that by eight months, infants increasingly rely on more language-specific cues such as word stress (e.g., Johnson & Jusczyk, 2001). By nine months, infants further show sensitivity to other segmental cues for speech segmentation in their native language: phonotactics (e.g., Mattys & Jusczyk, 2001a; Gonzalez-Gomez & Nazzi, 2013) and coarticulations and allophones (e.g., Johnson & Jusczyk, 2001; Mattys & Jusczyk, 2001b).

Although the studies summarized above allow us to roughly sketch the order and ranking of speech segmentation cues, note that there are still crucial pieces missing. First, most studies focus on one language (American-English); we do not know whether this shift from language-general to language-specific cues is also present in languages that differ widely from English (for similar discussions, see Johnson, 2012; Junge, 2017). Second, most studies present only positive evidence that infants can use a certain cue from a certain age, but do not test infants of younger ages (but see Jusczyk & Aslin, 1995; Jusczyk et al., 1999). Thus, we do not know whether a language-specific cue such as phonotactics can only be implemented once one has acquired sensitivity to word stress.

When infants segment novel words from speech, they appear sophisticated because they can immediately treat these words as possible word-candidates for novel meanings (Graf Estes, Evans, Alibali, & Saffran, 2007; Saffran, 2001). Nevertheless, infant word recognition skill remains rather fragile: infants often fail to recognize words across different speakers (Houston & Jusczyk, 2000; but see van Heugten & Johnson, 2012), across different dialects (e.g., Best, Tyler, Gooding, Orlando, & Quann, 2009; Schmale, Cristià, Seidl, & Johnson, 2010), or across different contexts

(Barker & Newman, 2004; Singh, Morgan, & White, 2004). Infants also need to hear the words multiple times before they start recognizing them embedded in continuous speech; for most infants, one exposure appears insufficient (Junge, Kooijman, Hagoort, & Cutler, 2012; Junge, Cutler, & Hagoort, 2014). In time, infants will gradually learn to cope with these indexical types of speech variation, presumably through increased exposure to different types of speech. Indeed, studies demonstrate that infant word recognition skill becomes more robust when infants listen to more varied speech (e.g., different speakers: Rost & McMurray, 2009; or different types of affect: Singh, 2008). All in all, through additional exposure to speech infants become more proficient in their ability to recognize words: they learn when variation in segmental or suprasegmental levels of speech highlights changes in word meaning (and when it does not). This suggests that mere exposure to speech is sufficient to bootstrap language from speech, but is this all infants require? The next paragraph discusses the interplay between speech input and brain maturation.

## Speech input and brain maturation

Throughout this chapter we have seen several examples of how speech perception within the first year of life becomes more and more language-specific, that is, shaped by the listener's native language. Clearly speech perception changes and improves as a function of time. Although it will take years before speech perception is considered mature, it appears that these changes are most pronounced in the second half of the first year. This led researchers to conclude that the first year of life forms a critical (or sensitive) period for speech perception (Kuhl et al., 2005; Werker & Hensch, 2015).

Critical periods are characterized as a window in time in which experience has a profound effect on development. For speech perception the critical period seems to fall in the first year. One key distinction of critical periods is that they appear plastic: their timing (that is, when they begin or end) can shift depending on changes in brain maturation or in exposure (Werker & Hensch, 2015). But what triggers the onset of this period for speech perception? Is it brain maturation or accumulated exposure to input that drives these changes, or a combination of both? Some insights are provided when examining infants with various types of atypical development.

Take the case of healthy preterm infants (born more than four to six weeks premature), who – compared to full-term infants – listen to comparable amounts of speech postnatally while their brains are still immature. If the critical period hinges solely on brain maturation, one would expect that the critical period would shift as a function of maturational (corrected) age rather than postnatal age. Here, studies on preterms show mixed results, depending on which aspect of language-specific speech perception is examined (Gonzalez-Gomez, 2017). Preterms appear to be delayed in their perceptual attunement when it concerns their sensitivity to language-specific prosody, e.g., to the rhythm required for language discrimination (Herold, Höhle, Walch, Weber, & Obladen, 2008; Peña, Pittaluga, & Mehler, 2010; but see Bosch, 2011) or to lexical pitch (Gonzalez-Gomez, 2017). Next, delays have also been reported for their phonological development (Peña, Werker, & Dehaene-Lambertz, 2012, but see Gonzalez-Gomez, 2017) and for word segmentation abilities (Bosch, 2011). However, preterms resemble chronologically age-matched controls in when their sensitivity to phonotactics appears (Gonzalez-Gomez & Nazzi, 2012; Gonzalez-Gomez, 2017). All in all, it seems that brain maturation greatly shapes the timing of the critical period: if the brains are immature, the timing of the critical period will also be delayed. But how relevant is the amount of input?

To test how (lack of) exposure contributes to the timing of the critical period, we can turn to children who are naturally deprived of any speech, because they are born deaf to hearing

parents. How does the early deprivation of speech affect their spoken language development? A growing literature suggests that the timing of when exposure to speech starts is critical: the later children have their hearing reinstated (i.e., after their first birthday), the less likely they are to catch up with their hearing peers, with delays particularly manifested in the domains of vocabulary and syntax (Caselli, Rinaldi, Varuzza, Giuliani, & Burdo, 2012). Similar delays in syntax are also present in another group of children exposed to their (new) native language relatively late: children who were internationally adopted at a mean age of 16 months (Gauthier & Genesee, 2011; although initial knowledge of their first language's phonology might unconsciously be preserved; Choi, Broersma, & Cutler, 2017). Some researchers suggest that these higher-level language delays can ultimately be linked back to the suboptimal critical period for speech perception, with negative cascading effects for subsequent stages (Werker & Hensch, 2015). Conversely, infants who are delayed in their speech exposure by less than 12 months reach similar milestones at the same speed (calculated from the moment they can hear) and in the same order as typically developing children (e.g., Dettman et al., 2016; Nicholas & Geers, 2007; cf. Levine, Strother-Garcia, Golinkoff, & Hirsh-Pasek, 2016). For example, research reveals that within six months of speech exposure, young infants with cochlear implants show similar phonological discrimination skills and rhythm biases as typically developing children (e.g., Vavatzanidis, Mürbe, Friederici, & Hahne, 2015, 2016).

Another way to test the contribution of language exposure is by comparing speech perception skills in infants raised in monolingual households versus those in bilingual households, as bilinguals receive a lower amount of language input than their monolingual counterparts do, and are therefore hypothesized to commit to their native language at a slower pace. Although it falls outside the scope of this chapter to describe at length the differences between monolinguals and bilinguals (see also Chapter 16, this volume), the general consensus is that bilinguals go through similar milestones, albeit sometimes slightly delayed, compared to their monolingual peers (cf. Werker, Byers-Heinlein, & Fennell, 2009). The pace of language acquisition in the dominant language is further mediated by the relative amount of exposure in that language: the more dominant a language is, the more the acquisition of this language resembles the pace of acquisition in monolinguals (Hoff et al., 2012). Together, such findings underscore that brain maturation as well as exposure to speech is fundamental for acquiring the skills to decode native speech.

## Concluding remarks and future directions

This chapter highlights that perceiving structure in speech is crucial for language development. The foundations of speech perception appear firmly in place by the end of the first year in life. In this year, children gradually become sensitive to different aspects of phonological development, with the influence of their native language starting to emerge over time. It is likely that this phonological and prosodic knowledge further aids future language development, such as vocabulary acquisition or even the acquisition of language-specific syntax. This latter hypothesis is known as the *prosodic bootstrapping hypothesis*, first proposed by Gleitman and Wanner (1982).

There are indeed encouraging signs that infant speech perception skill is fundamental for subsequent language development. Children with a genetic risk of language impairments, because either developmental language delays or dyslexia runs in their families, have also been shown to have atypical speech perception skills (e.g., van Alphen et al., 2004). Such atypicalities in speech perception are even noticeable in infancy, long before these children can be officially diagnosed as having language problems (e.g., Friedrich, Weber, & Friederici, 2004; Leppänen et al., 2002; see also Section 3, this volume). Moreover, a recent meta-analysis reveals that for typically

developing children, early speech perception connects to subsequent language growth at the individual level, for a variety of infant speech perception tasks that probe sensitivity to sounds, to words, or to prosodic knowledge (Cristia, Seidl, Junge, Soderstrom, & Hagoort, 2014). For instance, one study shows that early sensitivity to speech contrasts has different consequences depending on whether these contrasts are meaningful in the native language: whereas sensitivity to native contrasts yields positive correlations with lexical development, sensitivity to non-native contrasts in contrast appears to slow down lexical acquisition (Kuhl et al., 2005). Several studies on speech segmentation also reveal positive links with vocabulary growth (Newman, Ratner, Jusczyk, Jusczyk, & Dow, 2006; cf. Junge & Cutler, 2014).

Interestingly, not all advances in speech perception in the first year prove equally predictive; language discrimination, for instance, does not predict subsequent language performance (Newman et al., 2006). It remains unclear why some aspects of early speech perception skill prove more far-reaching than others. Is it simply that the critical period of speech perception actually marks a series of critical windows for aspects of phonological development (Werker & Hensch, 2015), and that once the critical period for language discrimination has been closed, sensitivity to this ceases to have an effect? Or could it be that the unit of a non-native language is less informative for a child than the units of sounds, words, or prosodic phrases within one's language? Moreover, note that most prospective studies focus on vocabulary size (but see, e.g., Höhle, Pauen, Hesse, & Weissenborn, 2014), but it remains unclear whether these links stretch to the acquisition of syntax, as suggested by the prosodic bootstrapping hypothesis. Future studies should examine whether individual differences in speech perception skill in infancy remain stable across childhood and predictive of language competence that goes beyond the lexicon.

Finally, while we focus predominantly on the emergence of speech perception skills in the first year, it is important to realize that the fine-grained aspects of speech perception are still not adult-like when children are 10 to 12 years of age. Compared to adults (cf. Diehl, Lotto, & Holt, 2004), children, for instance, discriminate less well between the small acoustic differences that cue phonemic contrasts (e.g., Elliott, Longinotti, Meyer, Raz, & Zucker, 1981; Hazan & Berrett, 2000). It is possible that further sophistication of speech perception requires full maturation of the auditory pathways (Elliott et al., 1981; cf. Nittrouer, 1996), which continues until children are about 10 years of age (Ponton, Eggermont, Coupland, & Winkelaar, 1992). Alternatively, children might require extended exposure to the ambient language to show adult-like perception (Nittrouer, Manning, & Meyer, 1993). A full description of children's sophistication in their speech perception skill is beyond the scope of the present chapter. However, while fine-tuning of speech perception spans the entire childhood period, we believe it is important to stress that the early and remarkably fast attunement to the native language starts in infancy.

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# 10

# ADVANCES IN EARLY SPEECH PRODUCTION

## Interactions with maturation, perception and learning

*Marilyn M. Vihman*

Contrasting approaches to phonological development differ in the way they characterize the adult grammar to be learned. Specifically, the formalist tradition long considered paradigmatic segmental contrast and distinctive features to be foundational (Jakobson, 1941/68; Clements & Ridouane, 2011); this was later supplemented by an emphasis on the syntagmatic units posited by the prosodic hierarchy (e.g., Demuth, 1996). The approach makes a sharp distinction between categorical, abstract grammatical knowledge of language, or *competence*, and the perception and production of speech, or *performance*. An underlying assumption is that while performance is variable and subject to error, competence, even in development, reflects stable, unchanging representations (e.g., Smith, 1973; Fikkert, 1994; Rose, 2018). Given this distinction, which is basic to most formalist approaches, it is usually a complementary assumption that without access to innate knowledge of the universal principles that underlie the structure of all languages (Universal Grammar, or UG) it is difficult if not impossible to explain how children gain such knowledge.

The contrasting view, variously known as functionalist or emergentist (MacWhinney & O'Grady, 2015), draws on usage-based and exemplar models (Bybee, 2001, 2010; Pierrehumbert, 2003b). Pierrehumbert (2003a) offers a rare outline of what adult grammar might look like in such an approach, or what phonological knowledge the child needs to acquire. One point is particularly important for our understanding of phonological development:

> *The phonological system is built while being used*. Since the knowledge that can be acquired at any time is dependent on the processing capabilities at that time, we can only understand acquisition in terms of the *relationship between processing and knowledge*.
>
> *(my italics, p. 117)*

This concisely expresses my own understanding of the developmental process, as should be apparent in what follows. In reviewing current ideas about advances in early speech production I will adopt the usage-based perspective, which makes it possible to pursue the basic research question of the origins of linguistic organization in the child from empirically supported foundations (maturation, exposure to input speech, vocal practice) rather than the alternative proposed in formalist models, in which disembodied parameter setting or constraint ranking is based on hypothetical access to UG or on purely maturational aspects of articulatory advance

(McAllister Byun, Inkelas, & Rose, 2016). With the question of origins in mind, I will focus primarily on the preverbal period and the first year of word production.

## The preverbal period

It is well established that infants are born with a vocal tract that more closely resembles that of non-human primates than that of human adults (Kent, 1992) – a vocal tract as yet incapable of producing the wide diversity of sounds used for distinguishing utterances in adult languages (Lieberman, 1984). The time course for change in the relevant anatomical structures remains unclear, because the relevant close anatomical and physiological studies of infants remain to be carried out (Vorperian & Kent, 2007). We only know so far that the process of vocal tract lengthening extends over a long period, with change occurring throughout childhood and, in males, additionally at puberty (Fitch & Giedd, 1999), and that the disparate anatomical structures of the vocal tract grow and change at different rates, so that "the young child has the task of learning to produce speech using an apparatus that is undergoing change" (Kent & Vorperian, 2007, p. 60; see also Vorperian et al., 2005, 2009).

At least two important points follow from this. First, the uniquely human capacity for speech must be directly related to the dramatic modifications to the vocal tract that are required, after birth, to make it possible. In contrast, the capacity for perceptual discrimination of human speech sounds, which appears to be in place within the first two to three months of life (for reviews, see Jusczyk, 1997; Vihman, 2014; Chapter 9, this volume), is of ancient lineage, having much the same neurophysiological underpinnings in other mammals (Hauser, 1996). Thus, Kuhl (1986) argued plausibly that speech production as we know it evolved to accommodate those perceptual constraints. Second, it is hard to see how infants could accommodate to the dynamics of vocal tract change without a deeply rooted propensity to "map" the changes through vocal exploration and practice (Mattingly, 1973) – procedures that are indeed fundamental to the development of other motor skills as well (Thelen & Smith, 1994).

### *The maturational onset of canonical syllables*

The developmental milestone widely understood to mark the beginnings of speech production is the emergence, in the middle of the first year of life, of canonical babbling. "Canonical babbling" is the term used for infant production of consonant-vowel (CV) syllables that reproduce the temporal characteristics of adult speech (Oller, 1980, 2000). These syllables are readily recognized as speech-like by caregivers; they emerge in parallel with a number of other "rhythmic stereotypies", or rhythmically based motor routines, that mark the onset of new motor skills as the infant begins to exercise control over the arms for reaching and the legs and torso for kicking, crawling and walking (Thelen, 1981; Thelen & Smith, 1994; see also Iverson & Fagan, 2004). The relatively predictable timing of the emergence of these syllables – between 5 and 10 months, broadly speaking, but more typically around 6–8 months – is a strong indication that they emerge on a maturational schedule.

We know from studies of deaf infants, whose babbling either begins much later or quickly fades (Oller & Eilers, 1988), that the ability to perceive speech affects an infant's persistence in producing these syllables; an important factor here must be the absence, in deaf infants, of the "self-reward" experienced by infants who can hear themselves producing adult-like speech sounds. However, no more direct influence of particular language environments on the shape of the first syllables has been detected; it is suggested that this advance is deeply rooted in evolutionarily ancient behaviors not originally related to speech production (MacNeilage, 1998).

When canonical babbling first emerges, the onset slot is restricted to stops and nasals, glottals and glides, the nucleus to low front or central vowels (e.g., [pæ], [ʔəmæ], [mæ̃::hæ̃], [pʻe:jɛ]): these are all taken from Deborah, at 9 months (Vihman, Ferguson & Elbert, 1986, Table 2). Davis and MacNeilage (1990, 1995, 2000) have provided ample evidence to support their frame-and-content hypothesis, according to which it is simple "mandibular oscillation", or "jaw wagging" (Meier, McGarvin, Zakia, & Willerman, 1997), that creates the closed-open gestural sequence first heard as a canonical syllable. Across numerous languages the make-up of these syllables has been shown to be roughly the same, with a tendency for preset C-V associations to predominate well into the period of babbling practice that follows (coronals are followed by more front vowels (e.g., [di]), velar consonants by more back vowels ([gu]), and labials by a neutral tongue setting that gives the auditory impression of a low central vowel [ɑ] or a mid-vowel or schwa ([bɑ, bə]). In the months after the emergence of canonical babbling and before word use can be identified, we can see vocal practice leading to "vocal motor schemes" (VMS: McCune & Vihman, 1987, 2001), consonants used with some frequency and consistency over several recording sessions, suggesting mastery of the motoric routine that underlies their production. In other words, individual "true" (supraglottal) consonants (consonants produced with obstruction of the airflow above the glottis) gradually come under the infant's voluntary control over the period of transition from babbling to word production, as evidenced by consistent use over time. The proportion of such vocalizations produced in this period provides one reliable predictor of later phonological advance (Vihman & Greenlee, 1987; see also McGillion et al., 2017). We can view such emergent consonantal mastery as providing at least three elements critical to the onset of word use: (i) the minimum basis required for identifiable production of most adult word forms; (ii) a platform for word-form retention in memory; and (iii) a prompt to caregivers that leads to supportive verbal responses. We address the social context below, offering a more extended account of the role of practice and the construction of phonological memory in what follows.

## *The role of social context in supporting infant vocalizations*

It is evident that language development does not occur in a vacuum. The social context is critical, not only because speech input provides an essential model for the child but also because involvement in vocal interactions supplies the motivation that drives learning. That is, contrary to the often repeated view that children "are trying to communicate effectively" by learning to process and produce speech-like sounds (e.g., Jusczyk, 1993), infants successfully communicate their needs and their affect from early on – through crying at first, and then smiles, pre-canonical vocal expressions of contentment such as cooing and, increasingly over time, meaningful gestures (Goldin-Meadow, Goodrich, Sauer, & Iverson, 2007). Furthermore, there is little reason to suppose that infants have any inkling of the value that the more adult-like communicative behavior of word use will bring once it is mastered.

Accordingly, it is worth looking at experimental research that has established a role for the social shaping of vocal advances, both before and after the emergence of canonical babbling. Already within the first three or four months of life researchers have observed exploratory movements of the mouth and tongue (Trevarthan, 1977; Stark, 1980); these are particularly likely to occur in the course of one-on-one interactions with others. Katherine Bloom (1975, 1977, 1988) first showed the effect of interactional situations on children of that age, commenting in particular that "eye contact [gives] social relevance to the adult's response" (Bloom, Russell, & Wassenberg, 1987, p. 213). Contingent adult responses were found to result in children more often vocalizing in a rhythmic, turn-taking manner, and also in a higher proportion of better controlled productions. Children's vocalizations, in turn, were found to have an effect on

adult listeners, who saw infants who produced more speech-like vocalizations as more developmentally promising, socially appealing and "intentional" overall (aspects of these studies, first conducted with anglophone Canadian dyads, were replicated with Italian and Japanese participants in Bloom, D'Odorico, & Beaumont, 1993; Masataka, 1993, respectively).

Hsu, Fogel, and Messinger (2001) pursued these ideas further within the more holistic theoretical framework of dynamic systems (Thelen & Smith, 1994), which led them to consider non-vocal events such as smiling and gazing on the part of both mother and child. As predicted, these maternal behaviors were related to more speech-like infant vocalizations; furthermore, symmetrical exchanges, in which infants respond to their mothers' efforts to engage them, featured infants' most advanced vocal forms (Hsu & Fogel, 2001). Such interactions were found to peak in frequency at about 4 months of age, after which the infants' interest and attention shift from the interpersonal to objects in the world (see also Lewis, 1936).

More recently Goldstein and his colleagues have begun to investigate the social shaping of vocalizations in the post-canonical period. Here again contingent (but non-vocal) maternal responses were seen to result in more frequent production and more advanced vocal forms in infants aged 7–10 months (Goldstein, King, & West, 2006; Goldstein & Schwade, 2008). And again, complementarily, mothers were found to give conversational bids most often in response to child CV vocalizations (Gros-Louis, West, Goldstein, & King, 2006). Thus, in the first months of life, as the child's neurophysiological capacity for producing speech-like vocalizations comes on-line, their experience of interactional exchanges with caring others supports and shapes their exploratory efforts and motivates further learning and development.

## *The effect of vocal practice on experience of input speech*

In a now classic study Ferguson and Farwell (1975) reported the surprising finding that children's first words tend to be relatively accurate; this follows from the fact that the words that they attempt to say are simple in structure and related to their existing babble patterns and must therefore in some sense be "pre-selected" for production. For some years it remained unclear how infants could know which word forms to attempt, as their metalinguistic capacities could hardly be sufficient to rule out challenging word targets. Equally surprising was the notion that phonological considerations should influence first word choices, which seemed more plausibly related, at a conceptual level, to whatever might capture an infant's attention. Nevertheless, experimental work confirmed the idea of phonological selectivity (e.g., Schwartz & Leonard, 1982).

In response to this paradox Vihman (1991, 1993, 1996) proposed that an implicit filtering mechanism – the "articulatory filter" – begins to function once speech-like vocalizations are in the repertoire. The now extensive literature on mirror neurons, discovered around the same time (di Pellegrino, Fadiga, Fogassi, Gallese, & Rizzolatti, 1992; Fadiga, Fogassi, Pavesi, & Rizzolatti, 1995), gives further credence to the suggestion that the emergence of a new motor skill alters the perceptual landscape (Campos et al., 2000). Vihman (2002) argues that mirror neurons emerge developmentally, based on the course of infant vocal development and word production; Cook (2012) comes to the same conclusion based on evidence from tool use.

The idea is that infants experience as particularly salient and memorable patterns in input speech that find an echo in their own vocal practice. Such a filter might highlight elements in running speech, supporting segmentation. (Note, however, that the possible role of production in this achievement has been consistently disregarded in the infant speech perception literature: see Vihman, DePaolis, & Keren-Portnoy, 2014). However, it would presumably be especially effective in the case of words that are repeatedly produced in isolation in the child's input. Such

words, which are relatively rare in input speech yet disproportionately represented at the outset of lexical learning (Brent & Siskind, 2001; Keren-Portnoy, Vihman, & Lindop Fisher, 2019; see also Chapter 9, this volume), include onomatopoeia (*bang*, *moo*, *woof-woof*, often repeated, in sequence: Laing, Vihman, & Keren-Portnoy, 2017), social expressions (*byebye*, *hi*, *no*, *thank you*) and interjections (*uh-oh*, *wow*); these account for one or more of the five or six words of 38 of the 48 children whose first-word data (from 10 languages) is provided in Menn and Vihman (2011).

A series of studies have provided some direct evidence to support the construct of an articulatory filter. In a study of Italian infants Majorano, Vihman, and DePaolis (2014) showed that those who have just begun producing one consonant with some frequency, across several recorded sessions (i.e., a VMS), will attend longer to a word list that features that consonant than to a similar list featuring a consonant they are not yet regularly producing.[1]

Paradoxically, this study also showed that infants who demonstrated use of more than one such stable consonant or VMS attended more to the contrasting word list, which featured consonants not yet in their repertoire. In an earlier study with British English-learning infants, similarly, DePaolis, Vihman, and Nakai (2013), who presented infants with two consonants of roughly equal input frequency in English but a sharp difference in infant production (common /t/ vs. rarely produced /s/), reported significantly greater interest in /s/ among infants with high production of alveolar stops (see also DePaolis, Vihman, and Keren-Portnoy, 2011).

Finally, Laing and Bergelson (2017) demonstrated that 10–11-month-old infants with one or more VMS, as established from an audio recording, responded 75% of the time, in a separate naturalistic video-recorded session, with congruent vocalizations to a parent's production of a word that included those consonants; in contrast, they responded only 31% of the time to adult productions that did not include the child's VMS. This builds on the idea of an articulatory filter and also refines Goldstein and Schwade's (2008) study of mother-child exchanges under contingent and non-contingent experimental conditions, demonstrating that infant responses to caregiver speech are "filtered through an inventory of their own well-established phonological structures" (Laing & Bergelson, 2017).

## *Ambient language influence*

There has been controversy as to whether the babbling period could be said to show "drift" toward the ambient language ever since Brown (1958) first proposed the idea. Ambient language effects on preverbal infant production should be found if, as many researchers assume, there is a relationship between perception and production within the first year. Several studies by Boysson-Bardies and her colleagues reported such effects (e.g., Boysson-Bardies, Sagart, & Durand, 1984; Boysson-Bardies, Hallé, Sagart, & Durand, 1989; Boysson-Bardies & Vihman, 1991), but other researchers have remained resistant to the idea (e.g., Thevenin, Eilers, Oller, & Lavoie, 1985; Davis et al., 2002; Engstrand, Williams & Lacerda, 2003). Davis et al., for example, conclude that "perceptual factors do not appear to play a very important role in determining the overall form of the output patterns" (p. 101). However, if we accept that infants are implicitly picking up on matches in the input speech stream to their own frequent production patterns, the kind of influence that has been reported – of vowel-space biases in line with the ambient language (Boysson-Bardies et al., 1989) or effects of input frequency on place or manner of infant consonant production (Boysson-Bardies & Vihman, 1991), for example – is to be expected: an existing infant motor routine that resembles patterns of common occurrence in input speech is most likely to be produced increasingly over time. (See Westermann & Miranda, 2004, for a computational model designed to test this conceptualization of ambient language influence.)

The findings of a recent study of adult listener judgments of infants exposed to English in the United States or Mandarin (and also Southern Min, or Taiwanese) in Taiwan are particularly relevant here. Lee, Jhang, Chen, Relyea, and Oller (2017) set out to apply unusually rigorous methods to test whether ambient language influence could be detected in the "pure babbling" of these infants at 8, 10 and 12 months. Bilingual Chinese-English- and monolingual English-speaking adults were asked to judge both the language background and the possible lexical status of each vocalization (based on sound pattern alone). Canonical and non-canonical vocalizations were also distinguished. The results revealed, as predicted, that the language background could not be correctly assigned to most infant utterances overall. However, language identification improved with infant age, with the bilingual Chinese listeners, at least, achieving correct judgments of the Chinese infants' vocalizations by 12 months (no other age or condition reached statistical significance).

Correct judgments were strongly associated with both presumed word status and canonicity, so that ambient language influence was related to infants' growing ability to shape their vocalizations to resemble common lexical patterns. Lee et al. conclude that although "pure babbling" may not show detectable ambient language influence, their findings "imply that detectable ambient-language effects are commonly . . . the product of influence from 'salient adult words' rather than from an abstraction of the phonetics of the ambient language that is independent of the lexicon" (p. 122). This is consistent with the view that perception and production are interconnected and mutually supportive in this period, with infants gradually gaining knowledge of the shapes of adult word forms and sequences and reflecting that implicit knowledge in their vocalizations.

## First word use

A child's first word use is a widely recognized developmental milestone, often recorded by parents and pediatricians. It is not easy to establish this landmark event reliably, however, for reasons that follow from the preceding discussion. The child's babbling moves gradually in the direction of adult speech, increasingly being limited to one or two syllables (Fagan, 2009). The first words are not only globally similar to babble (Oller, Wieman, Doyle, & Ross, 1976) but also, more specifically, show continuity with the babbling of the individual child (Stoel-Gammon & Cooper, 1984; Vihman, Macken, Miller, Simmons, & Miller, 1985). This then directly disconfirms earlier theoretical accounts (Jakobson, 1941/68): a given child's first words draw on the forms the child has been exploring through vocal practice; contrast between similar but functionally distinct sounds (phonemic contrast) is typically observed only later in development (Kiparsky & Menn, 1977; Macken, 1979).

With due allowance for the limitations of child production, the earliest words are, as Ferguson and Farwell (1975) first reported, consistently found to be relatively accurate renditions of their adult targets, regardless of the ambient language (Menn & Vihman, 2011). Accordingly, those targets largely share the characteristics of the first words produced cross-linguistically, differing only minimally by language. Vihman (2019) analyzes the first four to eight words of 38 children, each acquiring British or American English, Estonian, Finnish, French, Italian or Welsh. Across these seven groups the children attempt one- or two-syllable words almost exclusively, with some differences in distribution by language group; 89% of the child forms match the target in length. About one-third of the target words include more than one supraglottal consonant, on average. Codas occur in about half of the Welsh target words and in about a third in English, Estonian and French; Finnish has none; Italian only one (*biberón* "baby bottle").

Turning to the children's own word forms, most consist of one or two open CV syllables (just 8% of the 212 early words analyzed have codas, almost all in monosyllables; Finnish and Italian early words have none). Consonant variegation across the word is equally rare (8%, with

one or more such words in all groups except Finnish), again disregarding differences in voicing. Stops dominate these forms (60%), with 17% nasals, 7% glides and 6% "vowels only" (often with glottal stop or [h]); (supraglottal) fricatives, liquids and affricates are rare, together occurring in just 7% of the words. Half the forms (51%) include at least one higher-mid or high vowel; the remaining words consist of low to lower-mid vowels or schwa. Clusters seldom occur, but diphthongs are found in 17% of the child forms, mainly in British English, Estonian and Welsh.

These first word forms typically emerge from the vocalizations that accompany gestures, especially pointing (Iverson & Goldin-Meadow, 2005), in the course of episodes of joint attention; they can be taken to represent vocal responses to strong situational priming from the repetitive routines of daily life. The age of onset of stable consonant production, or VMS, has been shown to be the best predictor of age at first established word use (the "four-word point" (4wp), or recorded session with at least four child words: Vihman & Miller, 1988), surpassing both onset of pointing and maternal education (McGillion et al., 2017). McGillion et al., who based their study on analysis of longitudinal data from 46 children, noted a median age of 10 months for their measure of babbling onset (use of two VMS) and of 15 months for the 4wp.

What is the significance of this gap in time between gaining the phonetic skills needed for word formation and producing identifiable words? McGillion et al. argue:

> By starting to vocalize early, infants shaped their own environments, eliciting responses from the caregiver that (a) encouraged more vocal practice, (b) made it salient that vocalization can be used to communicate, and (c) assisted infants in identifying the function of first words.
>
> *(p. 162)*

In other words, once the child has mastered a small number of adult-like syllables, which come to be accessible at will, participation in these familiar situations prompts the linking of an existing vocal form (itself globally shaped by exposure to ambient speech) to a situational meaning. We have already claimed that the emergence of speech-like vocal forms provides the infant with a filter for adult speech, supporting implicit accommodation to frequently occurring features of that speech, within the limits of emergent infant neurophysiological capacities. Beyond that, vocal practice can be supposed to support the retention of more robust exemplars of individual word forms by giving substance to "phonological memory", or the ability to retain auditory patterns in mind for a brief period (Keren-Portnoy, Vihman, DePaolis, Whitaker, & Williams, 2010): this is the first deployment of phonological memory, which allows memory traces to be created of relevant "bite-sized" portions of the adult speech stream. Thus, it is not surprising to find that these first words are so often onomatopoeia, greetings and the like – high-frequency targets that are child-like in form, readily isolable from the speech stream without the added difficulty of segmentation (Brent & Siskind, 2001; Keren-Portnoy et al., 2019), and thus readily primed for production in a familiar episodic setting.

## Templates and emergent systematicity

### *Template formation*

How does the child advance further, lexically and phonologically, once he or she has made a start on word production? Articulatory change is slow, while the lexicon can grow quite quickly, once a child has come to appreciate the communicative and expressive value of word use. The child's problem soon becomes that of finding a way to produce more diverse and more challenging word forms, given limited articulatory skills.

The solution lies in supplementing lexical "selection" with "adaptation". That is, in addition to continuing to attempt target words whose pattern is already in their repertoire, the child now begins to target more difficult lexical items – words of more than two syllables, for example, in languages like Italian in which longer words are common (Vihman & Majorano, 2017), or disyllables with codas in English (Priestly, 1977). To do that before making the changes to their motor routines required for accurate production, they adapt the "hard words" to their existing patterns or "templates" – truncating long words, for example, or applying a fixed melodic pattern to simplify the challenge of consonant variegation in CVCVC forms (we return to Priestly's well-documented data below). Thus, in many although not all cases, as the child's vocabulary grows larger and more diverse, their output begins to conform to one or more favored patterns or templates; word forms become more similar to one another but less accurate. This constitutes an advance in systematicity along with a regression in accuracy. In other words, the child now extends to more challenging targets one or more well-practiced motor routines.

To illustrate the cross-linguistic validity and variety of templatic patterns in this period Table 10.1 draws on longitudinal data for one child each from five language groups. Each data set derives from a half-hour recorded session in which the child produced at least 25 different words spontaneously (the 25wp). Child age and total word types are given, along with a few

*Table 10.1* Templates in five languages.

*A. US English: Alice, age 16 mos., 34 words (Vihman, Velleman, & McCune, 1994). Palatal pattern <CVCi>*

| *selected word target* | *child form* | *adapted word target* | *child form* |
|---|---|---|---|
| *mommy* | əmɑ:mi$^{h}$ | *clean* | ti:ni |
| *daddy* | da:di | *elephant* | ʔeĭjĭ |
| *bottle/botty* | bɑɖɪ, pɑ:di | *flowers* | p'ɑ:ji, p'aɖi, fa:di |
| *bunny* | bʊɲ:ɪ, beɪŋji | *iron* | ãĭji |
| | | *lady* | lɛji, jɛ:ji |
| | | *mommy* | ma:ɲi, nɑ:ɲi |
| | | *shiny* | tɑ:ji, daji |

*B. Finnish: Eliisa, age 15 mos., 30 words (Vihman & Kunnari, 2006). Disyllabic consonant harmony. (Finnish orthography, which is largely phonemic, is used here;* ä *is* [æ].*)*

| *selected word target* | *child form* | *adapted word target* | *child form* |
|---|---|---|---|
| *kakku* 'cake' (i) | kak:o | *lintu* 'bird' | titu, tito |
| *kiikkuu* 'is swinging' | ki:k:u | *nuke* 'doll' | kuk:e |
| *kukka* 'flower' | kuk:a | *pallo* 'ball' | pap:u |
| *kukkia* 'flower, pP' | kuk:ia | *tippu(u)* 'to drop, drops' | pip:u |
| *pomppi* 'jump!' | pop:i | *vettä* 'water, sP' | tit:ɔ |
| *pupu* 'bunny' | pupo, pop:i: | | |
| *tyttö* 'girl' | tyt:ö | | |

*C. French: Béryl, age 18 mos., 56 words (Vihman & Wauquier, 2018). <aCV>*

| *selected word target* | *child form* | *adapted word target* | *child form* |
|---|---|---|---|
| *agneau* 'sheep' /aɲo/ | alo | *crapeau* 'toad' /kʁapo/ | ako |
| *encore* 'again' /ɑ̃kɔʁ/ | ɑ̃kɔ | *dauphin* 'dolphin' /dofɛ̃/ | afa |
| *etoile* 'star' /etwal/ | ata | *hibou* 'owl' /ibu/ | abu |

| *selected word target* | *child form* | *adapted word target* | *child form* |
|---|---|---|---|
| *un coeur* 'a heart' /ʌ̃ kœʁ/ | akɔ | *la pieuvre* 'octopus' /la pjoevʁ/ | apø |
| *une pomme* 'an apple' /yn pɔm/ | apɔ | *la tête* 'head' /la tɛt/ | atɛ |
| | | *les cloches* 'the bells' /lɛ klɔʃ/ | aχlo |
| | | *marteau* 'hammer' /maʁto/ | ato |
| | | *micro* 'microphone' /mikʁo/ | aχo |
| | | *perroquet* 'parrot' /pɛʁokɛ/ | ake |
| | | *sardine* 'sardine' /saʁdin/ | ani |

*D. Italian: Anna, age 20 mos., 27 words (Keren-Portnoy, Majorano, & Vihman, 2009). <(CV)CVlV>*

| *selected word target* | *child form* | *adapted word target* | *child form* |
|---|---|---|---|
| *bambola* 'doll' /bambola/ | bambala | *animali* 'animals' /aniˈmali/ | mali |
| *gallo* 'rooster' /gal:o/ | gal:o | *cappello* 'hat' /kaˈp:el:o/ | pɛl:o |
| *giallo* 'yellow' /dʒal:o/ | dʒal:o | *cavallo* 'horse' /kavaˈl:o/ | kalol:o |
| | | *maiale* 'pig' /majale/ | male |

*E. Welsh: Fflur, age 17 mos., 36 words. Monosyllabic consonant harmony. (Vihman, 2019)*

| *selected word target* | *child form* | *adapted word target* | *child form* |
|---|---|---|---|
| *diod* 'drink' /diɔd/ | dad | *beic* 'bike' /bɑɪk/ | gɛg |
| *gwag* 'empty' /gwɑg/ | ŋgak | *drwg* 'bad' /drug/ | gʊk, kʊx |
| *mam* 'mom' /mɑm/ | mam | *dwr* 'water' /dur/ | $k^{h}$ʊx |
| | | *fan'cw* 'over there' /vanku/ | $k^{h}$ux |
| | | *ffork* 'fork' /fɔrk/ | gaʊk |
| | | *rhein* 'those' /r̥ɑɪn/ | mɛn |

forms fitting the specified template, both selected and adapted. I will comment briefly on each of these patterns in turn.

Alice's "palatal pattern" has strong roots in her preverbal babbling, which featured unusually frequent production of yod (Vihman et al., 1994). At 16 months, when she produced over 30 words in the recording session, her strong tendency to shape words to such a pattern became hard to overlook. The selected adult words listed in the left column of Table 10.1 have the common English diminutive form <CVCi> (although *botty* is a family term, possibly adopted from Alice's form). The frequent occurrence of such words in the input may have inspired Alice's template, but the child goes well beyond them in producing words like those listed in the right column, with addition of [i] to *clean*; replacement of the medial consonant with yod or another palatal consonant in *lady*, *mommy* and *shiny*; and more radical reorganization of the target in the case of *elephant*, *flowers* and *iron*.

Two of the children – the Finnish child Eliisa and the Welsh child Fflur – both select and adapt words to the cross-linguistically most common "whole-word phonological process" (Grunwell, 1982) or template, consonant harmony (Vihman, 1978). Many targets are available to model the pattern for Eliisa's open disyllables, which are typical of her ambient language; to avoid the problem of consonant variegation Eliisa assimilates even early-learned onsets like /t/ (*tippu(u)* "drop[s]") or /n/ (*nuke* "doll") to the medial consonant (but reverses the direction of assimilation in the case of *pallo*, with its more difficult medial /l/). Otherwise, Eliisa's word forms are close to their relatively simple targets. The nasal clusters in *pomppi* "jump" and *lintu* "bird"

are simplified, but geminate consonants are produced as such; lengthening also occurs in words with target singletons (*pupu* "bunny" [pupo] but also [pop:i:], *nuke* [kuk:e]).

Selected target words are also available as models for the Welsh child Fflur's monosyllables with harmony; it is noteworthy that most of Fflur's adapted words show velar harmony, with truncation and addition of a velar fricative coda to create the favored $<C_1VC_1>$ pattern in the case of *fan'cw* "over there".

The <VCV> template seen in Béryl's word forms has not been observed in English, with its dominant trochaic stress pattern, but is common in iambic languages like French or Hebrew (Keren-Portnoy & Segal, 2016) and also in languages with medial geminates or with phonetically long consonants, like Estonian, Finnish, Italian and Welsh (Vihman & Majorano, 2017); in Béryl's case we can further specify the template as <aCV> (see *hibou* "owl" [abu]). With their many adaptations, Béryl's data show how a template, at the height of its functioning, can result in a very large number of similar word forms (and often homophones: cf. *une pomme* "an apple", *crapeau* "toad", both produced as [apo]).

Finally, the Italian child Anna shows her affinity for production of [l], selecting the words that naturally present themselves (*bambola* "dolly", *gallo* "rooster", *giallo* "yellow") but also truncating words in such a way as to retain the target /l/ while omitting other syllables (*animali* "animals", *cappello* "hat", *maiale* "pig"), and in one case retaining all three syllables of the target but harmonizing one consonant to /l/ (*cavallo* "horse"). (For similar templatic overuse of /l/ in French, another Romance language with function words in /l/, see Vihman, 1993.)

The children's templates differ in part due to ambient language differences, as noted, but differences between individual children also loom large; the various children in each group described in Vihman (2019) exhibit a range of distinct patterns.

## *Systematicity at the expense of accuracy*

Experimental work with novel word learning in adults (Gaskell & Dumay, 2003; Leach & Samuel, 2007) has added a notion of considerable potential importance to child lexical and phonological development in distinguishing (i) the registering of a new word form – that is, the initial memory trace – from (ii) the process of embedding the form in long-term memory, or integrating it into a systematically organized network that links lexical items along multiple dimensions. Gaskell and Dumay refer to the latter aspect of word-form learning as "lexicalization", while Leach and Samuel provide the term "engagement". This line of research is important for development because it emphasizes the process by which word forms are first retained and then integrated into the lexicon.

These two steps in adult novel word learning – one quick, the other slow – focus on word *form*; interestingly, they are paralleled, indirectly, by two steps recognized by McMurray et al. (2012) in relation to child language learning with a focus on meaning or reference: (i) initial word comprehension, the "situation-time" process of referent identification (in context), or *fast mapping*, and (ii) the necessarily slow ("developmental-time") process of *word learning*, which involves consolidation of a form-meaning link through multiple encounters or "naming events" (see also Chapter 11, this volume). The models are necessarily different: the word-form model was developed in studies of adults and older children, while the word-use model was designed to account for experimental findings relating to toddlers. Furthermore, both steps in the latter model involve repeated experiences of interlocutors' word uses, whereas the consolidation of word-form knowledge into a network of formal associations is primarily an internal cognitive process (and as such demonstrably aided by sleep: Dumay & Gaskell, 2007, 2012). Ultimately, a synthesis of the two models is called for, as multiple exposures are undoubtedly needed for

word-form learning as well, while the work of internal consolidation must apply to the networking of meaning as well as phonological associations.

The notion of lexical engagement provides a particularly useful starting point for understanding lexical and phonological development beyond babbling and first word production. The deployment of templates has been understood to reflect emergent systematicity, or the first organization of word-form knowledge (Vihman & Velleman, 1989, 2000), a move from individual item learning to the accommodation of cross-word similarities and differences within an incipient phonological network. This advance occurs at a time when the child's expressive lexicon is growing; it is almost certainly a factor in that growth, although the statistical modeling needed to demonstrate the connection has not yet been undertaken.

For templates to develop a child must have begun to link the internal representations of different words, which can be conceptualized in various ways. Vihman (2014) refers to "secondary distributional learning", in which the child *induces the patterns implicit in his or her own output forms*, themselves a compromise between what is easy for that child to produce and what is frequent and salient in the adult input the child is exposed to. Application of these induced (schematic) patterns to less phonologically accessible forms then results in the kind of templatic output we have described.

Alternatively, the adapted forms can be conceptualized as reflecting an *automatic extension of a familiar motoric routine* to those more challenging targets; the shift from selecting only to adapting as well as selecting word targets would then primarily reflect a *loosening of the child's filter* to admit more challenging forms as potential "matches" to the motoric patterns available.

Under either interpretation the advance in word learning must depend on an expansion of the child's cognitive capacities, which is likely due to both maturation, associated with advances in the neurophysiology of attention and memory (Richmond & Nelson, 2007; see Vihman, 2017, for a brief overview of relevant findings), and experience, given the evident prerequisite of a growing expressive repertoire. Increasing word knowledge likely translates into advances in the construction of phonological memory, for which expressive vocabulary appears to be particularly important (see, for example, Torkildsen et al., 2008, 2009, who show a significant relationship between expressive vocabulary size and receptive word-form processing). These developmental advances are also reflected in a change from context-limited or situationally primed word use to more adult-like referential or symbolic uses that no longer depend on prompting from the "here-and-now" (Bates et al., 1979; McCune, 1992, 2008; Vihman & McCune, 1994; Vihman, 2018). In other words, both template formation and referential word use require that the child implicitly bear in mind word forms and uses in one context when engaged in another; for phonological purposes, only relevant aspects of the template (e.g., <VCV>, harmonic <$C_1VC_1V$> – or, in the case of a melodic template, <$C_{[LAB]}VC_{[COR]}V$>; Macken, 1979) – need be activated for a new word to be adapted to the established form.

## Later advances

Although many studies report phonological template use in the early stages of word production, few have traced the path *away from* template use, or the gradual replacement of early holistic word-form learning, based on existing routines, by more accurate modeling of target forms. Among the studies that trace this path longitudinally are Priestly (1977), Macken (1979), Vihman and Vihman (2011), Szreder-Ptasinska (2012) and Oliveira-Guimarães (2013). Each of these considers both the emergence and the fading of templatic patterns. However, only the data Priestly provides in his classic study of his son Christopher (learning British English) allow one to follow the child's progress word by word, from production of the first "bisyllabic

experimental forms" – involving what we can now term a template, <CVjVC> – to exclusive production of "ordinary replacement forms".

At 22 months Christopher was producing a certain number of "selected" $CVCVC_o$ words whose medial consonant was either yod (*lion* /lajən/, *whale* /wejəl/) or a liquid (*carrot*, *pillow*). Once Priestly observed that other words were being adapted to the pattern and "it became clear that C was doing something not only amusing but systematic" (p. 45), he began noting the forms in his diary. These quickly increased in number (Wk. 3 of data collection, 12 new words; Wk. 4, 23; Wk. 5, 10; etc., up to 70 different words altogether with one or more template-based forms each). Replacement forms appear early on, however (e.g., Wks. 3, 4, 6 *banana* [bajan] but Wk. 5 [bánan]; Wk. 3 *doughnut* [dɛjawt] > Wk. 8 [dǽnɔt]). In fact, Christopher produces a regular replacement form already in Week 4 (*sucker* [fajak] > [fʌkə]), but some particularly frequent but challenging words, like *chocolate*, show a range of forms over the period, some template-based (Wks. 3, 6, 9 [kajak], Wk. 7 [kɔjak]), others related to the adult form through regular phonological processes (harmony, deaffrication, cluster reduction: see Wk. 6 [kákat]). Christopher's forms alternate between template-based and more segmentally accurate over the entire period of use, eloquently revealing how variable production patterns can be in this period, and how far phonological advances are from being categorical or "across-the-board", as sometimes claimed (e.g., Rose, 2018). Instead, we see fluctuations in attention or memory, with the favored template holding sway long after it is no longer required on the grounds of insufficient articulatory skill or control.

The remaining accounts, each covering several months of lexical development, report shifting shapes for any template over time and, in some cases, the emergence of one or more competing patterns. Although articulatory factors are clearly important, the child's "ambition" or "boldness" also plays a role, sometimes leading to periods of regression in accuracy as more challenging words are attempted. For example, a British child, Alison, produced relatively accurate forms with high segmental variability in her 25wp session, at 16 months (Szreder-Ptasinska, 2012). At 19 months she was attempting word targets with such challenging elements as fricatives, affricates, liquids and clusters, but avoiding the articulatory difficulty – and reducing variability – by relying for production on one of two templates, reduplication (especially for multisyllabic words and short phrases, such as *building blocks* [bəʊbəbɑː], *cup of tea* [gʊg:ɔgɔː], *gentlemen* [dʲɜdɜ:dɜ:]) or <ʔVGLV> (where GL is "glottal" or "glide": *flower* [ʔæ:wa], *office* [ʔəhʔɑ], *sausage* [ʔɒʔəː], *sorry* [ʔaɪjɑːʰ]). Alison's segmental variability increased again after her first template use, but the application of the templates remained lexically consistent. Alison was highly voluble and, thanks to template stability, intelligible as well, despite the adaptations. Szreder-Ptasinska ascribes Alison's template use to her willingness to try hard words despite an unusually small inventory of consonants.

## *The function of templates*

Templates serve a social or communicative function, making it possible for a child to enter more successfully into verbal exchanges; the context will often make the child's meaning clear enough for interpretation, especially once a template has taken hold and is used consistently over a period of days or weeks. Templates appear to facilitate and speed word learning (although see Velleman & Vihman, 2002, and Vihman, Keren-Portnoy, Whitaker, Bidgood, & McGillion, 2013, for evidence of children with developmental delays becoming "stuck" on template use). However, no real attempt has as yet been made to address the paradox of how templates might support phonological advance, given that they appear to limit a child's motivation or opportunity to extend their range of experience with production.

If templates reflect (secondary) *distributional learning*, based on the child's limited sample of articulatorily familiar vocal shapes, then the application of this knowledge to newly encountered input forms may serve primarily a memory function, supporting retention and phonological representation, however approximate, of increasing numbers of forms. Alternatively, if template use is taken to reflect the *extension of a motor routine*, assimilating less familiar word forms, then this essentially allows the child to bring a pattern of greater complexity than what is already in the repertoire within the compass of his or her articulatory experience, potentially making it easier to pick up on elements in the input that have been missing from the child's own production.

Additionally, again bearing in mind the social context of development, adapted, inaccurate word-form production will motivate adult responses, which should be particularly informative when the child has just produced a form; sporadic priming by an immediate model may well account for some of the variability in the data, when template-based and more "regular" forms occur in parallel. Thus, a template may serve the child by both (i) affording experience with some portion of the required phonetic sequence, which may serve to highlight the missing elements in heard speech, and (ii) provoking adult production of models to prime or help consolidate memory for the forms.

Phonological memory may be an important factor linking template use to lexical advance, given that the ability to recall and represent unfamiliar sound sequences or word forms is closely related to vocal practice and phonological experience (Beckman & Edwards, 2000; Edwards et al., 2004; Munson et al., 2012). We can conceive of the effect of verbal practice on improvements in memory for word forms, or phonological memory, as due to an increase in robust, neurophysiologically rooted knowledge of forms (segments, syllables, whole-word shapes) that permits on-line mapping of heard forms to existing representational patterns or exemplar clouds and, in the case of child output-based exemplars, to the articulatory subroutines and proprioception that underpin them.

As the child's consonant inventory grows with growing production experience, exemplars of adult forms will gain in precision; on the evidence, template formation supports that advance, meaning that word production, even if inaccurate, involves a linking of adult forms with multimodally represented child forms. Whether or not this then leads to advances in accuracy will depend on child sensitivity or attention to the differences between input and output exemplar clusters. This is an individual matter; we are far from understanding the mechanism of a shift from (i) primary reliance, for production, on internal representations (which we suppose to underlie extensive template use) to (ii) reliance on external input; the shift is undoubtedly gradual or intermittent, as we see from Priestly's data (see also the discussion in Menn et al., 2013). Further research involving dense recordings of production accompanied by experimental techniques such as eye-tracking or event-related potentials, which require no overt behavioral response or voluntary cooperation on the child's part, are needed to shed light on this question (see, for example, Renner's (2017) eye-tracking demonstration of the effect of children's phonological patterns on their attention to adult models); computational modeling could also elucidate the processes involved as the initial template-based network is replaced by one that is more segmentally based.

## *Speech production in older children*

Advances in speech development continue long after the period we have dwelt on here, not least as regards aspects of prosody (see, for example, Saaristo-Helin, 2009; Payne, Post, Astruc, Prieto, & Vanrell, 2012; Shport & Redford, 2014; Ballard, Djaja, Arciuli, James, & van Doorn,

2012; Arciuli & Colombo, 2016), although most children have mastered the basic segmental contrasts of their language by about age 4. For example, Foulkes and Vihman (2015) report the use of phonological processes in the spontaneous speech of 32 British children seen 14 months after their 25wp, at ages ranging from about 3 to 4 years. Of these children 21 were identified as late talkers at age 2, although in testing six months later about half of them ("transitional late talkers") fell within the norm for both expressive and receptive language use (Vihman et al., 2013).

The errors identified for the typically developing children, based on transcription of nearly 1000 utterances, were rare (see Table 10.2). All of the children occasionally produced /d/ for /ð/ (a dialect characteristic of some adult models, however), and most also sometimes omitted consonants. In the late talker group more errors were found, but even for those children the highest percentage of errors involved stopping of /ð/. Ten children in this group also displayed use of consonant harmony. In short, although the refinement of phonetic production undoubtedly continues well into the school years, the acquisition of most of the phonemes of the adult language can be expected to be more or less complete by age 4 in typically developing children (for cases in which development extends well beyond that period, see Chapter 19, this volume).

*Table 10.2* Phonological process use by children aged 2;4–4;2, based on transcription of 100-utterance samples for each child and ordered by tokens with errors in the speech of the typically developing children.

| | *Typically developing (TD: N = 11)* | | | *Late talkers (LT: N = 21)* | | |
|---|---|---|---|---|---|---|
| | *Tokens* | *%* | *Children* | *Tokens* | *%* | *Children* |
| stopping of /ð/ | 108 | 11.46 | 10 | 280 | 12.13 | 19 |
| /C/ deletion | 91 | 9.66 | 11 | 211 | 9.14 | 20 |
| velar fronting | 82 | 8.70 | 5 | 125 | 5.41 | 10 |
| gliding of /r, l/ | 67 | 7.11 | 9 | 168 | 7.28 | 17 |
| lisping | 58 | 6.16 | 7 | 115 | 4.98 | 14 |
| palatalization | 41 | 4.35 | 7 | 128 | 5.54 | 11 |
| gliding (other) | 37 | 3.93 | 7 | 48 | 2.08 | 7 |
| /C/ insertion | 32 | 3.40 | 8 | 81 | 3.51 | 16 |
| /l/ vocalization | 32 | 3.40 | 6 | 36 | 1.56 | 5 |
| weak syllable deletion | 26 | 2.76 | 6 | 84 | 3.64 | 15 |
| /Cr/ reduction | 25 | 2.65 | 6 | 61 | 2.64 | 8 |
| /sC/ reduction | 23 | 2.44 | 5 | 58 | 2.51 | 10 |
| fricativization | 20 | 2.12 | 6 | 71 | 3.07 | 14 |
| velarization | 20 | 2.12 | 4 | 71 | 3.07 | 10 |
| affricate reduction | 16 | 1.70 | 5 | 64 | 2.77 | 11 |
| /CC/ reduction (other) | 15 | 1.59 | 5 | 53 | 2.30 | 15 |
| /C/ harmony | 11 | 1.17 | 3 | 39 | 1.69 | 10 |
| labialization | 5 | 0.53 | 0 | 56 | 2.43 | 11 |
| TOTAL | 942 | | | 2309 | | |

*Note*: % = proportion of all errors identified in sample. Only errors produced by at least 6 TDs or 10 LTs are included. This table is based upon Foulkes and Vihman (2015).

## Summary and research questions

The most dynamic period of phonological development and change is undoubtedly the first two to three years of life. This chapter first addressed maturation, perception and learning in relation to the preverbal period, ascribing the universal appearance of canonical syllables in the middle of the first year primarily to maturation, for example. I reported evidence of the critical importance of social context for vocal development at several points as well and also concluded that there is little doubt of the ambient language shaping of preverbal vocalizations, particularly around the time of first word production.

We saw that the first words are rooted in a range of precursor behaviors, including both maturational articulatory advances and the vocal practice that supports and extends them. This is in strikingly good accord with Thelen and Smith's (1994) accounts of the development, in the same period, of walking and reaching, key motor skills which similarly depend on a combination of maturation and practice that is individual by child. In specific relation to speech we summarized the articulatory filter hypothesis (Vihman, 1993). This is the idea, now supported by experimental evidence, that input speech forms that are a rough match to a child's vocalizations thereby become especially salient to the child, supporting memory for those forms and priming production.

In the next phase of speech production, development draws especially heavily on accumulated lexical knowledge and the associated production practice of the individual child. Template formation was shown to take on different forms in different children, shaped to some extent by the target language but also by individual child strengths and experiences. We can assume that templates are also the product of "lexical engagement", or the implicit systematization of the word forms the child is producing. (Because the lexical advances of less expressive or more purely "selective" children are more difficult to track, we are unable to say to what extent *production* is key to this process of system-building, but it plays a clear role for most of the children whose phonological development has been followed over time.) However, so far we have only minimal information about the process by which templates are abandoned in favor of more faithful reproduction of adult models, when errors are found to affect individual segments rather than whole word forms.

A number of issues that arise from this account remain insufficiently explored. Prominent among these are the relationship between articulatory experience, the growth in diversity of lexical targets under the influence of template formation and phonological memory. New techniques as well as novel theoretical perspectives are likely needed to expand our understanding in these areas, along with a considered combination of experimental studies, which can provide the controls required to obtain answers to well-specified questions, and continued naturalistic, longitudinal observation of children learning a range of languages.

One question that has recently begun to attract more research attention is how best to conceptualize the child's developing lexical and phonological system itself – or that of the adult, for that matter. Purely linguistic approaches, invoking ever more constraints, for example, seem unlikely to advance our understanding here. Similarly, the long respected box-models of the speech production process, such as Levelt's classic model (1989), have begun to be challenged (e.g., Redford, 2015), but models to replace them remain underdeveloped.

From the perspective of speech processing, recent studies using computational modeling have begun to provide ideas as to the representation of linguistic knowledge in multiply layered and linked systems or networks. For adults, for example, Shook and Marian (2013) focus on the special (but widespread) problem posed by bilingual comprehension. They model the well-established effects of cross-linguistic interaction in lexical processing, proposing a network in

which formally similar exemplars cluster together, regardless of the language they derive from. For infants, Mayor and Plunkett (2014) extend the TRACE model of McClelland and Elman (1986) to simulate word-form recognition, finding that, here as in the present account of speech production and learning, lexical knowledge strongly constrains perceptual processes. (See also Werker & Curtin, 2005; Curtin, Byers-Heinlein & Werker, 2011.) As suggested above, what appears to be needed now is a model for infant advances in speech production that combines the steps that Leach and Samuel (2007) propose for word-form learning with the steps envisioned by McMurray et al. (2012) for word-use learning: both of these proposals address the systematization of the lexicon, and advances in the development of speech production are tightly bound up with both of them.

## Note

1 Note that differences in voicing are disregarded in these studies, given the evidence that children do not typically master this production distinction until their third year at the earliest (Macken, 1980).

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# 11

# LEARNING, RECOGNIZING, AND EXTENDING THE MEANINGS OF WORDS

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Learning words and building an effective vocabulary are the foundation of communication. Children need to understand the meanings of words both to comprehend what others are saying and to successfully communicate their own ideas, needs, wants, and feelings. There are three components of word learning: 1. initially determining the meaning of a new word in the moment, 2. remembering the word-meaning association over time, and 3. applying the newly learnt word to new instances or contexts (see Figure 11.1). Although these components are often discussed as if they were distinct processes, in reality, the child is working to solve all of these tasks in parallel. Each of these components is also the result of other processes such as the speech perception and visual attention required to determine the meaning of a new word or the understanding of statistical regularities in the input that enable extraction and generalization. Here, we review evidence of how children discover and extend word meanings in the moment and how they retain and recognize meanings over time.

## In-the-moment understanding of word meanings

### *Resolving ambiguity*

Historically, much of the literature on early word learning focused on the theoretical ambiguity posed by interpreting the meaning of words at a single moment in time. The philosopher Quine (1960) proposed that logically there is an infinite number of possible meanings one could consider when hearing a new word. On this view, mapping words to meanings should be practically impossible, yet most children learn the meanings of hundreds of words by the age of only 2 years (Fenson et al., 1994). This presumed paradox lead several theorists to assume that some elements of word learning must be innate (Gelman & Wellman, 1991; Markman, 1990). However, it has become increasingly clear that children receive rich input filled with informative regularities and signals that is not nearly as ambiguous as previously thought (McMurray, Horst, & Samuelson, 2012; Smith & Yu, 2008; Tamis-LeMonda, Kuchirko, & Song, 2014; Tomasello & Barton, 1994).

Young children are introduced to many words through social interactions that constrain in-the-moment interpretations of word meaning because they occur within shared space and time. For example, during in-home everyday routines, parents typically name objects that are

physically present, and the child is often touching or holding the named objects while the parent or both the parent and the child are looking at them (Custode & Tamis-LeMonda, 2018). Head-camera research using a first-person perspective of children's social interactions reveals that because children have short arms, most of their views are close-ups of a single object, while most of adults' views are further away with multiple objects in view (Smith, Yu, & Pereira, 2011; see also Chapter 7, this volume). That is, children's own bodies can resolve ambiguity. Critically, if caregivers name the object the child is holding, then from the child's perspective there is no ambiguity in what is being named. Indeed, children are more likely to learn the words used in these "good naming moments" than words used in more ambiguous moments (Yu & Smith, 2012). In addition, adults shown videos of mother-child interactions in which selected words have been muted are surprisingly accurate in identifying the referent of the muted utterance (Gillette, Gleitman, Gleitman, & Lederer, 1999). Taken together, such findings suggest that the structure of social interactions serves to constrain interpretations of word meaning.

## *Iconicity*

Another source of information that can influence the meanings children give to words is the forms of the words themselves. Young children and adults are sensitive to iconicity, or the correspondence between word sounds and meanings, for example looking longer at a pointy shape when hearing a word like "kiki" or at a round shape when hearing a word like "bouba" (Köhler, 1947; Ozturk, Krehm, & Vouloumanos, 2013). The iconic properties of a word may help children identify its meaning from a chaotic context and generalize this meaning to new occurrences.

Japanese and many other languages have special classes of words, called "mimetics" or "ideophones", that tend to be very high in iconicity. For example, in Japanese mimetics, "korokoro" refers to a light object rolling repeatedly, and "gorogoro" refers to a heavy object rolling repeatedly. Both Japanese and English speaking preschoolers can more accurately associate the meanings of novel verbs to the action rather than the agent when those verbs are structured similarly to Japanese mimetics than when the verbs have a more arbitrary relationship with their meanings (Imai, Kita, Nagumo, & Okada, 2008; Kantartzis, Imai, & Kita, 2011).

Although linguists have traditionally argued that Indo-European languages, especially English, are essentially arbitrary, several recent studies have found traces of iconicity in the lexicons of English and Spanish. Perry and colleagues (2015) obtained native speaker ratings of iconicity for the words on the English and Spanish versions of the MacArthur-Bates Communicative Developmental Inventory, a list of the first ~600 words children produce in each language (Fenson et al., 1994; Jackson-Maldonado et al., 2003). They found that in both languages, the words rated highest in iconicity tend to be acquired the earliest (e.g., bubbles, icky). This finding held even after controlling for other known predictors of age of acquisition, including concreteness and frequency. Similar results have been found in studies of signed languages as well (Vinson, Cormier, Denmark, Schembri, & Vigliocco, 2008). Together these findings suggest that iconicity may serve to aid in children's early word learning (cf. Imai & Kita, 2014).

Subsequent research expanding the ratings to 3,000 English words examined the relationship between the perceived iconicity of words and their frequency in different types of speech, i.e., children's speech, adults' child-directed speech, and adults' speech to other adults (Perry, Perlman, Winter, Massaro, & Lupyan, 2017). Highly iconic words tend to be used more often by children than less iconic words, and adults tend to use highly iconic words more often when speaking to children (mushy, icky) than speaking to adults (granular, asymmetrical). Together, these results suggest early parent-child conversation is characterized by iconicity – even though language, in general, is not.



*Figure 11.1* Three common tests in the word learning literature include referent selection (cf. fast mapping), where a child chooses an object in response to a novel name, typically in the presence of other objects for which the child already knows names (left); retention tests, where a child chooses a previously named novel object in the presence of other novel objects (middle); and novel noun generalization, where a child is shown an exemplar of a category that is named and chooses between an object that matches the exemplar in shape and an object that matches the exemplar in another feature such as material or color (right).

## *Word learning biases*

In addition, a number of word learning constraints may reduce the number of meanings under consideration. For example, a word refers to the whole object rather than a part (see Markman, 1990), or social constraints may cause children to have skilled understanding of other people's minds and use that knowledge to constrain their meanings (see, e.g., Akhtar, Carpenter, & Tomasello, 1996; Baldwin, 1993). In addition, children use syntactic cues to differentiate between an object (a sib), a substance (some sib), and an action (sibbing; Bishop, 1997; Brown, 1957). Parents often label whole objects before labeling object parts (Masur, 1997), and children learn that names tend to refer to whole objects (Markman, 1991). Speakers also tend to follow the convention to use words that are known to everyone in the conversation; therefore, unknown words tend to refer to something for which a word is not known (Clark, 1990, 1993). In addition, names contrast in meaning so that an *apple* is not a *pear*. Together, these conventions and contrasts can aid children in using the mutual exclusivity principle (Markman & Wachtel, 1988). For example, if a child knows that that one is called "apple" and that one is called "pear", then this new fruit must be the "quince". However, the cross-situational statistics of name-referent co-occurrences are strong enough to enable children to behave as if they are using mutual exclusivity without top-down knowledge (McMurray et al., 2012; Gillette et al., 1999; Custode & Tamis-LeMonda, 2018). The word "apple" is heard more often in the context of the object apple than the word "quince". For a further review of cues to word learning, see Mattock Kalashnikova and Monaghan (2017) and Houston-Price and Law (2014).

### *The novelty bias*

When children are asked to determine the referent of a new word from an array of familiar objects and a single novel, nameless object, they reliably choose the novel object (Mather & Plunkett, 2012; Merriman, Marazita, & Jarvis, 1995). This behavior is consistent with both employing the mutual exclusivity bias (Markman, 1990) and solving the task through process-of-elimination (Halberda, 2003). However, computational modeling demonstrates that this behavior can

arise without any top-down knowledge (McMurray et al., 2012). Further, the behavior is likely driven by children's endogenous bias toward novelty (see, e.g., Kucker, McMurray, & Samuelson, 2018).

When children are asked to determine the referent of a new word from an array of only novel objects, they reliably choose the most novel object present (Akhtar et al., 1996; Diesendruck, Markson, Akhtar, & Reudor, 2004; Horst, Samuelson, Kucker, & McMurray, 2011). The most novel object may be the object most recently added to the array (Mervis & Bertrand, 2008; Wilkinson, Ross, & Diamond, 2003), most recently played with (Akhtar et al., 1996; Diesendruck et al., 2004), or played with in a unique way (Samuelson & Smith, 1998). Horst and colleagues (2011) demonstrated 2-year-old children's endogenous novelty bias by giving children novel objects to explore for 2 minutes and then asking children to determine the referent of a new word from an array of two previously seen novel objects and a single "supernovel object". None of the objects had been associated with any names so the trials could not be solved by mutual exclusivity or process-of-elimination, and children should be equally likely to choose any object. However, children were significantly more likely to choose the supernovel object. This study was later replicated with 3- and 4-year-old children (Dysart, Mather, & Riggs, 2016), who exhibited the supernovel bias for both novel names and novel actions and with the iCub robot (Twomey, Morse, Cangelosi, & Horst, 2016). A similar effect was observed by Mather and Plunkett (2012) when they presented 22-month-old toddlers with sets including a familiar object (shoe), a previously seen novel object, and a supernovel object.

Children's endogenous bias toward novelty has led several researchers to advocate that a minimum of two novel named objects be included in any research design (Schafer & Plunkett, 1998; Axelsson & Horst, 2014; Delle Luche, Durrant, Poltrock, & Floccia, 2015). When an experimenter names only one object, children may choose this object at test simply because it was the odd one out. Naming an object draws children's attention to the object (Mather & Plunkett, 2012; Waxman & Markow, 1995). Axelsson and Horst (2014) presented two groups of 2-year-old children with the same objects and the same task. For one group of children all of the objects were named, but for the other group only one object was named (the other objects were only referred to as "this one"). When only one object was named children were 15 times more likely to "correctly" identify the named object at test. This simple demonstration reveals how easily children can appear to perform well on word learning tasks for the wrong reasons. There may be cases when testing a single word is appropriate, such as exploratory research. However, we can only test whether children learned the correct word-object associations when at least two objects are named (Schafer & Plunkett, 1998).

## *The shape bias*

Across development, children acquire word learning biases leading them to attend to relevant information when learning the names for novel nouns. For example, by about 2 years of age, children have acquired a "shape bias", generalizing the names of novel solid objects by similarity in shape rather than similarity in material or color (Landau, Smith, & Jones, 1988). This bias emerges from regularities in children's early vocabulary. In English, the majority of words children learn early name solid objects in categories well organized by similarity in shape (e.g., ball, spoon; Samuelson & Smith, 1999). As children learn more about individual categories, which tend to be organized by similarity in shape, they form a higher order generalization – that names *in general* refer to categories organized by shape. Thus, as children's vocabulary grows, they begin

to show a shape bias (Gershkoff-Stowe & Smith, 2004; Samuelson & Smith, 1999). Vocabulary knowledge trains children's attention to shape similarity (cf. Smith, Jones, Landau, Gershkoff-Stowe, & Samuelson, 2002).

Further evidence in support of the link between vocabulary knowledge and the shape bias comes from cross-linguistic studies. The biases children develop depend on the regularities of the language they are learning (Smith, Colunga, & Yoshida, 2003). For example, children learning Japanese are more likely to generalize the names of simple solid objects by similarity in material than similarity in shape, but they generalize the names of complex solid objects by similarity in shape just as English learners do (Imai & Gentner, 1997). Additionally, children learning Spanish are overall less likely to generalize by similarity in shape (Hahn & Cantrell, 2012). However, this difference appears to be driven by differences in the way syntax is associated with object solidity and category organization in English and Spanish. In particular, in Spanish the same object can be talked about using either count or mass determiners (*a* wood vs. *some* wood) depending on the meaning the speaker has in mind (a discrete item vs. the material). In English, count and mass determiners are more tightly linked to particular categories and their organization (a table vs. some wood). Compared to English learners, Spanish learners are much more sensitive to syntax cues, generalizing by shape in the context of count syntax ("a wug") and material in the context of mass syntax ("some wug"; Colunga, Smith, & Gasser, 2009), because of the flexibility in syntax use in the Spanish language (Gathercole, 1997).

A series of longitudinal training studies demonstrate that vocabulary knowledge *causes* the development of the shape bias (Perry, Samuelson, Malloy, & Schiffer, 2010; Smith et al., 2002; and see Samuelson, 2002, for evidence from computational simulations). Teaching 1.5-year-old children – who have not yet developed the bias on their own – the names of categories organized by similarity in shape leads them to develop a precocious shape bias and acquire vocabulary more quickly, even outside of the laboratory. Following the training, the children in these studies who acquire a precocious shape bias begin acquiring new vocabulary at double the rate of their peers.

### *Environmental context and action patterns influence biases*

In addition to learning about solid objects like "cup", children also learn about nonsolid substances like "yogurt". When generalizing the names of novel nonsolid substances, children must attend to material ("material bias"). The material bias develops later than the shape bias (Samuelson & Smith, 1999) and is less robust and more easily influenced by the specifics of the task and stimuli used than the shape bias (Samuelson & Horst, 2007). Nevertheless, even very young infants have some perceptual expectations about how solid and nonsolid things should behave. The difficulties children have in thinking about nonsolid substances seem to be tied specifically to the task of word learning. One reason for this difference is that learning about nonsolid substances is constrained. Early-learned names for nonsolids are foods seen at mealtimes, such as milk and applesauce. Solid objects, on the other hand, are seen in many contexts – some are foods, some are toys, and some are household items or pieces of furniture. When 16-month-olds sit in a highchair in the lab, the same context in which they typically learn about nonsolids and material at home, they are more likely to show a material bias than their peers who sit at a standard laboratory table (Perry, Samuelson, & Burdinie, 2014).

An additional difference in the way children learn a material bias is that materials are difficult to recognize from static visual information and may require tactile information (Lederman & Klatzky, 1990). Indeed, in the highchair study, the children who touched stimuli the

most showed the strongest material bias, and, critically, it was those in a highchair who touched stimuli the most (Perry et al., 2014). Those in the highchair were messiest because that setting increased context-dependent action patterns that proved necessary for recognizing similarity between materials (cf. Perry, 2015). Indeed, there is further evidence that the actions that children perform influence the word meanings they form. For example, Smith (2005) found that when 2-year-olds were taught to move novel objects up and down, they later generalized that name to another object that was relatively elongated along its vertical axis rather than one that was relatively elongated along its horizontal axis. Children's interpretation of the word's meaning was dependent on the actions they performed.

### *Individual differences in-the-moment*

Individual differences reveal how vocabulary knowledge influences the biases children show. Children with language impairments tend to show delayed or atypical biases. For example, 2–3-year-old children with autism spectrum disorder tend not to show any systematic bias when generalizing the names of novel objects (Tek, Jaffery, Fein, & Naigles, 2008). Many children who are late talkers, with a productive vocabulary below the 30th percentile for their age, show a slight bias to generalize novel names to objects of the same texture, rather than the same shape (Jones, 2003). Other studies of late talkers, including computational simulations, reveal more heterogeneity in their word learning biases relative to typical and early talkers (Colunga & Sims, 2017). Children with hearing loss who use cochlear implants have more difficulty remembering the shapes of newly learnt objects compared to their typically hearing peers (Quittner, Cejas, Wang, Niparko, & Barker, 2016). Although it is not clear exactly why children from any of these groups should be showing different word learning biases, what is clear is that they all share difficulties or delays in their expressive vocabulary, highlighting the tight link between vocabulary and the shape bias.

There are even notable individual differences within typically developing populations (Perry & Samuelson, 2011). For example, most English-learning children who know many names of solid objects in categories organized by similarity in shape tend to generalize novel names by similarity in shape. However, children who know many names for solid objects in categories organized by *material* (e.g., chalk, ice, chocolate), generalize novel names by similarity in material. Moreover, individual differences in vocabulary knowledge predict systematic differences in children's recognition of familiar objects (e.g., Fernald, Perfors, & Marchman, 2006). For example, when children were shown pairs of familiar animals and foods whose prototypical colors had been switched (e.g., a pink cow and Holstein-patterned pig), children who knew relatively few words for categories organized by shape were less likely to look at the named picture (Perry & Saffran, 2017). Clearly, there is a tight link between existing vocabulary knowledge and the meanings children ascribe to novel words.

## Later understanding of word meanings

Theoretically, resolving lexical ambiguity should be nearly impossible (Quine, 1960), and yet, paradoxically, some have argued that children learn the meaning of a word after only a single encounter. Over the past decade numerous studies and reviews have demonstrated that what children learn from their first encounter with a new word is, in fact, only partial knowledge that is very fragile (Carey, 2010; Horst & Samuelson, 2008). One minute after hearing a new object labeled, children are unable to repeat more than about 30% of the phonemes in its name (see Figure 4 in Munro, Baker, Mcgregor, Docking, & Arciuli, 2012). Five minutes after hearing a

new object labeled, 2-year-old children are unable to recognize which object was named – even when only one of the objects present had been named (but see Holland, Simpson, & Riggs, 2015, with older children; Horst & Samuelson, 2008). And yet hundreds of studies claim to demonstrate successful word learning by young children (Golinkoff, Hirsh-Pasek, Bailey, & Wenger, 1992; Markson & Bloom, 1997; Woodward, Markman, & Fitzsimmons, 1994). What this tells us is that we have been 1. misinterpreting children's baseline and 2. underestimating the support children receive to help them encode and consolidate new word learning.

The most highly cited source of children's awe-inspiring word retention abilities is the seminal demonstration of "fast mapping" by Carey and Bartlett (1978), although only approximately 16% of the children fully retained the novel color word (Carey, 2010). In the original study, a preschool teacher asked 14 3–4-year-old children (individually) to help prepare a snack. She asked children to fetch "the chromium tray, not the blue/red one, the chromium one". With the support of lexical contrast, 13 of 14 children fetched the olive green (not red) tray. Carey (1978, 2010) notes that children could solve this referential ambiguity by exclusively relying on "not the blue/red one" and without attending to the novel color word. Most children asked for confirmation ("you mean this one?"), and many repeated an approximation of the target word. A week or so later, children were asked to select "chromium" from a series of eight color chips that included olive and seven focal colors, including green. It is possible that children could have solved this task through process-of-elimination because preschool children already know a variety of color terms (e.g., Pitchford & Mullen, 2002), these particular children had been participating in a longitudinal study that involved a variety of color term assessments, and all but one of these children reliably used six to 11 color words (Carey, 1978). In addition, only one novel color term was introduced, which could conflate performance (Horst & Samuelson, 2008; Schafer & Plunkett, 1998). Many children chose green or olive green on the color chip test. (The original paper does not report results for these two colors separately, however; Carey (1978) reports children often chose green when asked for "chromium".) In a follow-up study, an additional 20 3.5-year-old children were given a similar color chip test that now included maroon, red, and purple approximately 7–10 days after their first encounter with the target word. These children were also re-exposed to chromium 10 months later before being given a second color chip test. Over the course of several assessments such as color sorting, these children received multiple exposures to the target word. Nine and 12 children chose olive or a similar color on these tests, respectively, but these rates were not different from a non-exposure control group. Carey later reported, "Over the two studies, only 2 of 34 children had fully mapped 'chromium' to the color olive green by the end of testing" (2010, p. 186).

## *Supporting later word learning*

In these original papers, Carey (1978; Carey & Bartlett, 1978) explicitly argued that fast mapping was only the beginning of an extended process and that children do require multiple exposures to words before they are fully learned. Research since has confirmed that repetitions facilitate full word learning (e.g., Mather & Plunkett, 2009), as do social-pragmatic cues like eye-gaze (e.g., Yow et al., 2017), gesture (e.g., Capone & McGregor, 2005), and pointing (e.g., Booth, McGregor, & Rohlfing, 2008; Grassmann & Tomasello, 2010), as well as reducing the initial referential ambiguity through naming objects in predictable locations (Benitez & Smith, 2012). Telling children an object "is special" (Vlach & Sandhofer, 2012) or "is yours" (Axelsson, Dawson, Yim, & Quddus, 2018) also improves children's memory for the name-object associations. Sleep plays an important role in word learning as well. For example, when 2-year-old children

nap after learning object names via disambiguation trials, they are more likely to remember the names than peers who do not nap (Axelsson, Swinton, Winiger, & Horst, 2018; for similar effects with other age groups, see also Horváth, Myers, Foster, & Plunkett, 2015; and Weighall, Henderson, Barr, Cairney, & Gaskell, 2017 and see Chapter 8, this volume).

Providing ostensive naming when words are initially introduced also facilitates full word learning (e.g., Axelsson, Churchley, & Horst, 2012; Bedford et al., 2013; Hilton & Westermann, 2017). Here, ostensive naming refers to explicitly naming the referent for the child, which can occur before (e.g., Dollaghan, 1985) or after (e.g., Axelsson, Churchley, & Horst, 2012) children solve the referential ambiguity. In their review of the conflicting findings of the then extant literature on children's word learning via fast mapping, Horst and Samuelson (2008) concluded that many of the studies demonstrating word learning from minimal exposures had included some elements of ostensive naming. For example, both Dollaghan (1985) and Oviatt (1980) had named the target objects when no other objects were present. Such naming events are necessarily explicit and reduce all ambiguity.

However, ostensive naming often involves moving the objects being named and isolating them in children's visual fields. For example, Horst and Samuelson (2008) demonstrated that 2-year-old children could only retain words introduced during referent selection trials if additional support, such as ostensive naming, was provided. In their task, ostensive naming involved moving the target object away from the name-known competitor objects and then pointing to the object once it was isolated in the child's visual field. When naming takes place during play, if parents name objects as children isolate them in their field of vision, children are more likely to learn those names (Smith et al., 2011). Moreover, spatial segregation of objects during play may also create "good naming moments" (e.g., always keeping Toy A on the left and Toy B on the right). This consistent use of space helps children learn the meaning of new words by helping them bind the name to the object in memory (Samuelson, Smith, Perry, & Spencer, 2011; see also Morse, Benitez, Belpaeme, Cangelosi, & Smith, 2015). When parents teach their children the names of two novel objects, children's performance on a subsequent comprehension test is positively correlated with the consistency with which each of the objects was kept to the right or left of the child (Samuelson et al., 2011).

Reducing the extraneous information present during the initial naming exposure also facilitates full word learning. This can be done by including fewer objects in the visual scene (Horst, Scott, & Pollard, 2010), showing fewer scenes at once (Flack & Horst, 2018), or repeating the familiar objects with which the novel target objects appear (e.g., Axelsson & Horst, 2014; Kucker & Samuelson, 2012; Twomey, Ma, & Westermann, 2017). For example, Axelsson and Horst (2014) presented 3-year-old children with multiple three-item referent selection trials (two familiar objects and one novel object) before testing their ability to learn novel word-object associations. When children saw the same sets repeated across trials (e.g., the clacker was always presented with the elephant and cup), even if the objects changed locations across trials, they were significantly more likely to learn the novel word-object association than when these sets differed across trials (e.g., the clacker appeared with the elephant and cup, train and frog, and ball and cow). Note that in this task the familiar objects (elephant and cup) are already known and should not be the focus of children's attention. Whether there was repetition on the control, familiar word trials had no effect. The effect was exclusively driven by the repetition of extraneous information when the novel names were introduced. However, the advantage of repeated extraneous information disappears for 22-month-old children if the background color changes from white to gray at test (Twomey et al., 2017). Children are better at recognizing previously seen objects and backgrounds separately than they are at recognizing object-background pairs (Lloyd, Doydum, & Newcombe, 2009).

Similar effects have been observed in more naturalistic tasks when children are taught words incidentally through shared storybook reading (looking and listening while an adult reads an illustrated book; Ard & Beverly, 2004; Robbins & Ehri, 1994; Sénéchal & Cornell, 1993). For example, Horst and colleagues (Horst, Parsons, & Bryan, 2011) read children either the same storybook three times or three different stories and then tested how well children recognized the target word-object associations that had incidentally appeared in the stories. This was repeated three times over the course of one week, and children's retention of the word-object associations for the words from the first two visits were tested at the end of the third visit. All children had the same number of exposures (tokens) to the same number of novel words. However, the children for whom the extraneous information (here the stories and their background illustrations) was repeated learned significantly more words than the children for whom the information was not repeated. This effect was particularly strong on the final retention test when children from the repeated stories condition were still remembering 66% of the target word-object associations, but children in the different stories condition were responding at chance levels (25%).

The word learning benefit of repeatedly reading the same stories has been demonstrated by many labs (McLeod & McDade, 2011; Sénéchal, 1997; Robbins & Ehri, 1994; Ard & Beverly, 2004). This effect is even more pronounced when children are read to before sleeping (Williams & Horst, 2014). Importantly, this effect has been replicated in children with developmental language disorder (e.g., Rohlfing, Ceurremans, & Horst, 2018).

Many studies present children with 12 exposures (tokens) of the words in storybooks, often through a mix of repeated stories and multiple exposures within each story (e.g., Horst, Parsons, et al., 2011; Justice, Meier, & Walpole, 2005). Children with developmental language disorder may require twice as many exposures to target words as their typically developing peers (Gray, 2003). Building on this finding, Storkel and colleagues (2017) conducted an intervention study with children with developmental language disorder in which they systematically varied the number of word exposures. Word learning improved with number of exposures for children receiving 12, 24, and 36 exposures to each word, but no additional benefit was found for 48 exposures. Children with larger vocabularies, better phonological awareness, and nonword repetition learned the most words.

Asking children to repeat the target names can also help with remembering the name-object associations (Vlach & Sandhofer, 2012). However, encoding cues hurt production in typically developing children (Gray & Brinkley, 2011). In general, it is very difficult to elicit production in referent selection tasks, with reports of children producing less than one out of eight words (Horst & Samuelson, 2008) or less than one out of 12 (Gray & Brinkley, 2011; see also Childers & Tomasello, 2002). Pinkham, Neuman, and Lillard (2011) have demonstrated that 24 repetitions are typically necessary before 4-year-old children could successfully name a new single novel object. To test children's phonetic knowledge of a new word, a more effective assessment than pure production is the spatially supported forced-choice recognition task developed by Gordon and McGregor (2014). In this task, the experimenter introduces the child to new object names and then places a piece of paper with dots on the table. Pointing to each dot in turn, the experimenter asks the child if the object was called the target name ("dorb"), a closely related name ("vorb"), or an unrelated name ("zinnip"; Gordon et al., 2016). The advantage of this task is that children make a manual response based on recognition (as they do during referent selection trials) instead of a verbal response based on recall as in production tasks.

## *Extension errors*

When children do produce words, they occasionally make errors. The errors children make when they generalize words to new instances can give us insight into the meanings they assign

to the words they know. Young children frequently make over-extension errors, generalizing words more broadly than adults would. These errors are typically driven by similarity between the correct meaning and the new instance. For example, children make errors based on perceptual similarity, calling a horse "doggy" or the moon "ball" (cf. Clark, 1973), or based on functional similarity, calling a Frisbee "ball" (cf. Nelson, 1974).

Gershkoff-Stowe (2001) has found that as children's vocabulary increases, so does the frequency of their extension errors. There is a curvilinear trend in children's extension errors for a given word (Gershkoff-Stowe & Smith, 1997; Rescorla, 1980), suggesting that initially children might extend a word rather narrowly, leading them to be accurate in its use. As they gain more experience using a word, they begin to broaden their understanding of meaning, leading to an increase in extension errors. With subsequent learning, however, children fine tune their understanding of the scope of a word's meaning and increase their accurate extensions.

### *Remembering words for categories*

Finally, 2-year-old children learn word-category associations better than single word-object associations, at least when the within-category variability is not too great across exemplars (Twomey, Ranson, & Horst, 2014; see also Vukatana, Graham, Curtin, & Zepeda, 2015, for sound-category associations). Specifically, when introduced to category names via disambiguation trials, toddlers will remember the names for categories for which the exemplars only varied in color, but not the names for categories for which the exemplars varied in color and slightly in shape or size (Twomey, Ranson, et al., 2014), though children generalize names for more variable categories at higher rates (Twomey, Horst, & Morse, 2014; Perry et al., 2010). Further, children remember shape words better than color or texture words (Heibeck & Markman, 1987), and object names better than shape, color, or texture words (Holland et al., 2015). However, they are even more able to remember the actions performed on the objects (Holland, Hyde, Riggs, & Simpson, 2018). The same domain-general mechanisms that support action learning may support word learning (Riggs, Mather, Hyde, & Simpson, 2015).

### *The importance of forgetting*

Somewhat paradoxically, a central component of remembering the meanings of words is forgetting. Forgetting is especially relevant to extending words to new instances of a category or in a novel context or setting. In order to correctly extend a word, the child has to ignore or forget information that is irrelevant to the actual meaning. An apple is an apple whether it is in a bowl or on a tree and whether it is a bright green Granny Smith or a tricolored Pink Lady. To remember the relevant information about its shape, texture, and taste, a child has to forget all the other stuff. Recent work on children's learning has increasingly focused on the forgetting process, showing that, for example, when learning events are distributed over time, allowing children to forget, they learn better than when learning events occur in quick succession (Vlach & Kalish, 2014). This "spacing effect" applies to children's ability to learn and generalize both new conceptual information (Vlach, 2014; Vlach & Sandhofer, 2011) and new word-object associations (Slone & Sandhofer, 2017; Vlach & Johnson, 2013). For example, in a cross-situational word learning task, 16-month-olds are better able to remember which labels co-occur with which objects and are more accurate when object-label pairs were distributed over time than when they appeared in succession (Vlach & Johnson, 2013).

Relatedly, although many sleep studies suggest napping after learning a new word increases children's ability to recall it, as discussed above (Axelsson, Williams, & Horst, 2016; Horváth

et al., 2015; Williams & Horst, 2014), there is also evidence for increased generalization accuracy following a period of wakefulness, but not following a nap (Werchan & Gómez, 2014). The period of wakefulness between learning and generalization allowed for more events to be interleaved between them, similar to learning in the spacing effect studies. When the child experiences more irrelevant events after learning, it should increase their forgetting, allowing them to recall only the most relevant or salient information later at test – the information necessary to generalize a word to a novel category instance.

Of course, forgetting too much is not helpful to recalling and generalizing words. Notably, we see developmental changes in how quickly children forget different kinds of information about newly learned objects. For example, as children develop, it takes them longer to forget objects' shapes, a change that is associated with their ability to accurately generalize novel objects by similarity in shape (Vlach, 2016). Similar to these developmental differences, there are also *individual* differences in memory and forgetting processes, and these differences relate to children's cross-situational word learning abilities (Slone & Sandhofer, 2017; Vlach & DeBrock, 2017).

### *Individual differences over time*

Additional individual differences exist in children's ability to remember and recognize words' meanings over time. For example, although several studies have failed to find a correlation between overall vocabulary and word retention (e.g., Kucker et al., 2018; Horst et al., 2010; Deák & Toney, 2013), increasing evidence suggests that vocabulary knowledge also influences what children remember about individual words' meanings over time. Children who know more words for objects in categories organized by similarity in shape are more likely to pay attention to shape when learning about new objects (Perry & Samuelson, 2011; Gershkoff-Stowe & Smith, 2004; Samuelson & Smith, 1999). For example, Perry and colleagues found that 2-year-old children who know many words for categories organized by similarity in shape are more likely to remember novel objects' shapes, but not their materials or colors, than their peers with similar vocabulary sizes who know relatively fewer words for shape categories (Perry, Axelsson, & Horst, 2016). Together, these results demonstrate that early in development, words do not have fixed meanings, but rather individual differences in children's experiences and knowledge influence what children remember about words' meanings (Perry & Saffran, 2017).

Individual differences in temperament also influence how well children retain the meanings of words (Salley & Dixon, 2007; Dixon, Salley, & Clements, 2006; Dixon & Smith, 2000; Garello, Viterbori, & Usai, 2012). Children whose parents rate them as shyer than their peers are also less able to retain word-object associations. Hilton and Westermann (2017) introduced 2-year-old children to four novel word-object pairs using referent selection trials with two familiar objects and one novel object. Across trials children were asked for either a familiar object for which they already knew a name (e.g., car) or a novel object (e.g., a tea strainer called koba). Shy children were significantly less accurate than their peers on both trial types. Retention trials with only novel objects were presented after a short 5-minute delay. Although there was no main effect of shyness, unlike their peers, shy children did not retain the objects' names at rates greater than chance.

## Conclusions

Historically, children have been credited as amazing word learners who can learn up to nine new words per day (Carey, 1978). Research over the last 40 years has revealed the various supports and quality of input that are required to support full word learning and effective word generalization.

Such research indicates that young children can learn up to four new words per day (Bion, Borovsky, & Fernald, 2013; Horst & Samuelson, 2008), which, although more modest, remains an amazing accomplishment. Nevertheless, much is still left unknown about young children's word learning and generalization. Rather than focusing on questions of *how many* or *how quickly*, future research should investigate the actual *hows* of word learning, such as the mechanisms connecting in-the-moment attentional processes with extended learning processes. As our colleagues' chapters in this volume indicate, the future of this research is here. A real understanding of word learning mechanisms requires increased exploration of the nature of children's everyday experiences outside of the laboratory; increased focus on individual differences, atypical learners, and multilingual learners; and increased collaboration between experimental work and computational simulation. Only then can we truly understand the amazing task of word learning.

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# 12

# LEARNING LANGUAGE FROM THE USE OF GESTURES

*Katharina J. Rohlfing*

The extensive research on the multimodality of communication in recent years has generated many reviews on how gestures support learning. The present review focuses on the learning of language. It addresses the question of how children can communicate via gestures from an early age and how gestures, being a part of a learning situation, can enhance memories about the learning content. In the first part of this review, a differentiation between gestural types is introduced. Subsequently, a key feature of gestures, namely, their coordination with other modalities and with the dialogue partner, is addressed. In the third part, the role of gestures as a precursor to language skills is set out, followed by a section on the benefits of gestures for learning different language skills in younger and older children. Finally, explanations for why gestures support learning are reviewed.

## Gestural types

The term "gestures" comprises movements performed with the hands and other body parts (head, shoulder) as well as small face movements (eye brows, eye gaze). Whole body movements can also be considered as gestures, for example, when a child is hesitating to approach another person. In the literature, bodily movements are considered to be gestures when they occur within a communication and as a function of the coordination between participants. In this sense, Goodwin (1980), for example, studied how movements of the eyes are used by interaction partners aiming to contribute something to the conversation. These kinds of communicative gestures are called *pragmatic gestures*; they "help [in] negotiating aspects of the situational embedding" and guide the organization of the discourse (Wagner, Malisz, & Kopp, 2014, p. 209). They are considered informative because they allow inferences about the interaction partner's attitude, state, or level of agreement (Wagner et al., 2014).

When investigating the benefits of gestures for language acquisition, most studies have focused on movements of the hands and referred to these as *representational gestures*. Whereas a moving away from the partner can be informative, a hand gesture bringing an object into the foreground is not only informative but also part of the speaker's verbal expression. Such gestures contribute symbolic content to an utterance (Kendon, 2004) and, when performed while speaking, are referred to as *co-speech gestures*.

When combined with speech, the content conveyed in a hand gesture either can be *redundant* to the verbal information or can *add* "a new semantic element to the meaning of the spoken word" (Morford & Goldin-Meadow, 1992, p. 560). From early on in ontogenetic development, the hands are those body parts that are coordinated with vocalizations (Iverson & Fagan, 2004). Different phases can be observed during co-speech gesture production: 1. a *preparation phase*, in which a hand is moving from the resting position; 2. a *stroke*, as a peak in movement performance; and 3. a *retraction phase*, in which the hands are returning to a rest position. For the construction of meaning, the "maximum of information density" is attributed to the stroke phase, and this phase is considered to be decisive for whether gestures are redundant or add content to the verbal message (Wagner et al., 2014, p. 210). Within representational gestures, further types can be differentiated. The most relevant ones for studies on language acquisition are defined below.

## *Deictic gestures*

The function of deictic gestures is to raise a referent to the domain of scrutiny. Whereas gaze can also indicate a referent, a deictic hand gesture relates to 1. *showing*, such as holding up an object and thus controlling the line of sight; 2. *indicating*, for example, singling out a person, object, or location by direct contact; and 3. *pointing*, such as directing the extended index finger or whole hand toward a referent. The semantic process here requires the observer to "relate the gesture to the situation" (Marcos, Ryckebusch, & Rabain-Jamin, 2003, p. 217).

This gestural form is one of the first that can be understood in early infancy (Rohlfing, Grimminger, & Lüke, 2017). Initially, the meaning of a pointing gesture is borne by its dynamic motion toward a referent. Accordingly, 6-month-olds will follow a dynamic but not a static pointing gesture (Rohlfing, Longo, & Bertenthal, 2012). Obviously, infants first need to experience pointing within communicative episodes before they become able to infer its meaning from a static presentation without additional cues (Flom, Deák, Phill, & Pick, 2004; Rohlfing et al., 2017).

Deictic gestures are the first representational gestures to occur. As a means applied in interactions, they can be observed in 9-month-olds (Tomasello, Carpenter, Call, Behne & Moll, 2005), and they are the gestures that infants produce predominantly at this early age (Iverson, Capirci, Longobardi, & Cristina Caselli, 1999; Morford & Goldin-Meadow, 1992). The function of these early gestures refers primarily to the here and now. However, Liszkowski, Carpenter, and Tomasello (2007) found that 12-month-olds also use pointing gestures to mentally turn to something not visible that had been present in the past (see also Bohn, Zimmermann, Call, & Tomasello, 2018; Gómez, 2007).

With respect to a specific deictic gesture, namely, the pointing gesture, Rohlfing et al. (2017) have concluded that there is growing support for changes in the form that appear during development: from indicating with the whole hand to using the index finger to point out things and events (Liszkowski & Tomasello, 2011; Lüke, Grimminger, Rohlfing, Liszkowski, & Ritterfeld, 2017). The use of the pointing form (with whole hand or with the index finger) seems to be related to individual differences in language development: At 12 months, infants who pointed only with their whole hand – and not with their index finger – were at risk for delays in their lexical and grammatical skills at 2 years of age (Lüke, Grimminger, et al., 2017).

The hand form of pointing is easier to differentiate than the motives of pointing, such as *imperative pointing* with the goal of obtaining an object or bringing about an event; *interrogative pointing* as a way to request information; *declarative pointing* for the purpose of mere interaction with an adult; or *informative pointing* to provide the partner with needed information (see

Rohlfing et al., 2017). Whereas these motives capture the possible intentions of learners, many studies reveal that children point because they are following the partner's motives by monitoring her or his knowledge and interest (Liszkowski, Carpenter, Striano, & Tomasello, 2006; Liszkowski, Carpenter, & Tomasello, 2007).

### *Conventional gestures*

These are ritualized acts in the form of emblems such as holding the hand in refusal or waving good-bye. They are communicative and can replace verbal behavior (Kettner & Carpendale, 2013). Capone and McGregor (2004) highlight that this type of gesture emerges early in development, between 9 and 13 months of age, as a form of ritualized and accepted request, in contrast to, for example, less mature whining or fussing.

Comprehension of these gestures is linked to the question of when children recognize conventional acts. Negation gestures are the best examples, because they are "invariable and always understandable within a given culture" (Marcos, Ryckebusch, & Rabain-Jamin, 2003, p. 217). Kettner and Carpendale (2013) observed that infants need to perform the movement (in their case, shaking their heads from side to side) before using it for a communicative purpose (namely, refusal). This observation is interesting, because it suggests that infants need to put the gesture's reliability to the test by experiencing its function in order to comprehend its meaning.

### *Iconic gestures*

This kind of arm movement serves to represent an object or event by depicting some relevant aspects of it (e.g., the shape of an object). The main function of this gesture is to evoke a referent, even without its presence.

Although Vogt and Schreiber (2006) report that iconic gestures are produced around 12 months of age, other longitudinal studies of children's spontaneous gestures found that children produce very few iconic gestures from ages 11 to 24 months (e.g., Acredolo & Goodwyn, 1988).

The comprehension of this kind of gesture is evident quite late in comparison to deictic gestures. Stanfield and colleagues (2013, p. 8) propose that compared to deictic gestures, the reference of an iconic gesture might be "less straightforward", because it links up with some features of the selected referent (e.g., if the referent is an object, it can express aspects of an action that can be done with it as well as some of the object's attributes such as its shape). This might impose "additional cognitive challenges for young children" – for example, to augment the interaction with aspects that are not present in the ongoing situation. Indeed, whereas 18-month-olds are able to learn an iconic gesture with which to refer to an object, children comprehend the iconic nature of the gesture at no earlier than 3 years of age (Vogt & Kauschke, 2017). In fact, recognition of the iconic meaning seems to develop gradually starting from 2.5 years (Tolar, Lederberg, Gokhale, & Tomasello, 2008).

Concerning the particular iconic characteristics that can be captured by a gesture, Capone and McGregor (2004) report that when learning new words for objects, toddlers benefited from a shape gesture more than from a gesture taking up functional aspects of the referent. Whereas only a few iconic techniques (such as shape vs. function) have been studied for children's comprehension, they appear to be manifold in children's gesture production. In a recent longitudinal study, Cartmill and colleagues (2015) have proposed a taxonomy for studying early iconic gestures: 1. *hand-is-hand* gestures that occur when an action is actually imagined and enacted within a kind of pantomime, for example, performing the action of brushing teeth as if somebody were holding and using a toothbrush; 2. *hand-is-object* gestures in which a body part models an object,

for example, when the index finger is standing for the toothbrush and the performer is moving it as if brushing her or his own teeth; and 3. *tracer gestures* that are performed with a pointing finger but provide some symbolic information or a pattern by drawing the shape or the movement in the air (see also Kendon, 2004, who uses the categories *modeling*, *enacting*, and *depicting*; Streeck, 2008). The results of this longitudinal study by Cartmill et al. (2015) suggest that hand-is-hand gestures occur first and are then followed by the other types.

## Crucial aspects in the use of gestures

The previous paragraph presented the gestural types as a fairly flexible taxonomy. For learning taking place within social interaction, however, assigning this behavior to a particular type is of less importance. It is much more relevant to consider gestures in relation to some crucial aspects of their use. These aspects are: 1. the relation to the immediate context (i.e., whether the gesture is referring to present entities and can thus rely on them as resources for meaning creation); 2. the iconic content (i.e., the way in which the motor performance of the gesture takes up characteristics of the referent); 3. the perspective it expresses (e.g., whether the gesture expresses a character's or an observer's viewpoint); 4. the conventionality (i.e., the way the form is established to transmit a particular meaning); 5. the temporal synchronization with other behaviors; and 6. the synchronization with a partner. Some of these aspects have already been addressed in this review, and the following paragraph will focus on synchronization.

### *Intrapersonal synchronization of gesture with other modalities*

What changes during development is not only the types of gestures (deictic gestures performed in a specific manner and increasingly more diverse iconic gestures) but also their coordination with other modalities such as eye gaze and language. The change in types and increasing simultaneity between modalities enables a transmission of the meaning "across the senses" (Gogate, Bahrick, & Watson, 2000, p. 879). The term "synchronization" refers to a correspondence between two modalities in time, such as gesture and speech, commonly resulting in their occurrence overlapping. The coordination of gestures with language has been described as a *convergence point* (Butcher & Goldin-Meadow, 2000; McEachern & Haynes, 2004) at which children apply units of different behavior either redundantly or complementarily in their meaningful expressions after the onset of first word production (Esteve-Gibert & Prieto, 2014). At this point, the production of gestures without words decreases, whereas the number of gesture-speech combinations increases. During the first combinations of gestures with words, the prosodic features of speech (i.e., the accented syllable) become synchronized with the gesture's apex (i.e., the moment when the finger is maximally extended). This converging point, reflecting an integrated gesture-speech system, is prepared from early on by infants as young as 6 months of age through coordinating their vocalizations with rhythmic hand movements (Iverson & Fagan, 2004). Soon after, a co-expression of mainly deictic gestures with vocalizations can be observed, even before infants produce their first words (Esteve-Gibert & Prieto, 2014).

### *Interpersonal synchronization of gestural behavior*

The term "joint attention" refers to routinized patterns of attention that can be characterized as the moments when two partners manage to focus on the same object or event and are aware of this joint engagement (Baldwin, 1995; Tomasello, 1995). In such routines, infants at the age of 18 months can be seen to coordinate their gestures (and gaze) systematically to ascertain that

the partner is looking at them before they perform a gesture (Franco & Gagliano, 2001). This kind of synchronization with other partners increases as children gain in interactional experience. Interactional experience is achieved in various routines requiring the coordination of the partners' attention (Bruner, 1983; Rohlfing, Wrede, Vollmer, & Oudeyer, 2016). Routines thus organize partners' perception of objects and events and require the partners to engage in joint actions. One such routine is a labeling routine in which the infant needs to follow or initiate attentional cues to perceive a referent for the purpose of labeling. Akhtar and Gernsbacher (2007, p. 195) rightly point out that the term "joint attention" is also used more broadly, and that many researchers use it to mean "a whole complex of [. . .] 'social cognitive' behaviors" including the ability to understand others as intentional beings that is attested to infants at the end of their first year of life (Tomasello, Carpenter, & Liszkowski, 2007). In fact, recent research suggests that social coordination can be achieved even without gaze and merely by looking at each other's hands and manipulative actions (Yu & Smith, 2013).

## Gestures as precursor to language

"At a time when children are limited in what they can say, there is another avenue of expression open to them [. . .]. Children can gesture" (Goldin-Meadow, 1999, p. 423). Generally, representational gestures that children can perform at an early age are rightly viewed as a precursor to language. In a recent study, the number of representational gestures infants produced at 9 months was predictive of their vocabularies 3 months later (Cadime, Silva, Santos, Ribeiro, & Viana, 2017). Even more far-reaching results were reported by Rowe and Goldin-Meadow (2009), who found that the number of gestures used at 14 months explained larger vocabularies at 54 months in children coming from high-SES backgrounds. Looking at Italian learners, Sansavini and colleagues' (2010) longitudinal study revealed a supporting effect of gestures on the emergence of verbal abilities. Interestingly, the authors also found a gender effect, with girls gesturing more than boys.

Several studies have shown that the number of gestures performed specifically for the purpose of joint attention, and thus requesting the children to coordinate with their caregivers and to engage in reference to objects and events, correlated positively with the size of children's early vocabularies (Carpenter, Nagell, Tomasello, Butterworth, & Moore, 1998; Tomasello & Farrar, 1986; see Akhtar & Gernsbacher, 2007, for a summary). Mundy and colleagues (2007) identified and operationalized several patterns of joint attentional behavior. In a longitudinal study, they found that responding to the partner's gaze and pointing at 9 months and initiating such cues to guide the partner's attention at 18 months both predicted language development at 24 months. Among the various joint attention behaviors, the literature highlights the role of early pointing gestures: In their meta-analysis, Colonnesi and colleagues (2010) concluded that pointing gestures – especially those produced with a declarative motive – related concurrently and longitudinally to language development. Beuker et al. (2013) confirmed the significant relation between the production of declarative pointing gestures at the age of 9 months and expressive language skills at the age of 19 months. The same pattern can be found in Özçalışkan and colleagues' (2016) study, revealing that deictic gestures correlated with children's expressive vocabulary tested one year later.

Not only the number of first gestures but also their form can be indicative of individual differences in language development. In a longitudinal study, Lüke, Grimminger and colleagues (2017) revealed recently that children who followed a typical path of language development at 24 months pointed more with their index finger at the beginning of their first year of life. Nonetheless, it is not clear how long this relationship remains a strong one. Whereas Colonnesi

et al.'s meta-analysis (2010) suggested that the relation between pointing gestures and language becomes stronger with age, in particular toward the end of the second year of life, Akhtar and Gernsbacher's (2007) revealed that during the second year of children's lives, the magnitude of this relationship between joint attention and vocabulary development seems to decrease or disappear.

When seeking explanations for this strong relation between early gestures and later language skills, it can be noted critically that it reflects a kind of expressivity that is inherent to some children. Another possibility, however, is that this relationship reveals some communicative experiences that are advantageous to language development (see Section 3, this volume). To narrow down the nature of this relationship, more studies with special populations are needed. One such recent longitudinal study was conducted by Lüke and colleagues (Lüke, Grimminger, et al., 2017; Lüke, Ritterfeld, et al., 2017). With respect to the relationship between pointing and language development, they found that it is the synchronization of pointing gestures with speech and not the mere use of pointing that is crucial for children who seem to be delayed in their language development at the age of 24 months (see also Grimminger, 2017).

Synchronization with speech occurs as "a robust feature of communicative development" (Capirci, Iverson, Pizzuto, & Volterra, 1996, p. 645) and increases between the ages of 16 and 20 months in the form of combinations of gestures with vocalizations or words. This synchronization for the purpose of creating a meaningful utterance seems to be linked tightly to later language skills: Typically developing infants combine gestures with words on average of 2 months before producing their first two-word combinations (Iverson & Goldin-Meadow, 2005). In a longitudinal study, Lüke, Ritterfeld, and colleagues (2017) revealed that this synchronization occurs significantly less at the end of the second year of life in children who seemed to be delayed in their language development at 24 months: They gestured without using words at 21 months, and this behavior stood in contrast to the behavior of typically developing peers.

What appears imperative is that combinations of gestures with words predict later aspects of syntactic language development (e.g., Igualada, Bosch, & Prieto, 2015; Iverson & Goldin-Meadow, 2005; Rowe, Özçalişkan, & Goldin-Meadow, 2008). Taking a closer look at supplementary combinations such as pointing to a couch and saying "push", Özçalişkan and Goldin-Meadow (2005) investigated combinations between words as well as words and gestures in 14-, 18-, and 22-month-olds. They found that the supplementary type of gesture-speech combination presages changes in children's speech (ibid., p. 110). More specifically, Cartmill, Hunsicker, and Goldin-Meadow (2014) found that combinations consisting of a noun and a point predicted the onset age for combinations of a determiner and a noun within speech. It thus seems probable that "the ability to use gesture and speech together to convey different components of a proposition is a harbinger of the ability to convey those components solely within speech" (Goldin-Meadow, 1999, p. 423).

Even for more advanced language learners, gestures continue to be "a harbinger of change in speech" (Demir & Goldin-Meadow, 2016, p. 278). In this context, Demir and colleagues (2014) investigated how gestural behavior predicts later narrative skills. Between 4 and 5 years, children's narrative skills improve significantly. Starting from the assumption that simulating "narrative events from a first-person perspective appears to confer benefits on narrative comprehension and memory" (ibid., p. 4), the authors investigated what kind of perspective children take verbally and gesturally. In fact, gestures can be performed either from the perspective of a *character* who is involved in the events and actually acts; or from the viewpoint of the *observer* who reports about the events facing them as a third person. The authors found that children at the age of 5 years were more likely to tell better structured stories at a later age when they expressed a particular viewpoint – namely, the character's – in gestures, but not when they

expressed it in speech. Another recent study (Stites & Özçalışkan, 2017) augmented these results with findings from children aged 4 to 6 years. It analyzed their way of introducing new story characters: Expressing the new characters from a character's viewpoint first in combinations of speech and gesture was found to be related to later conveying "the same referents exclusively in speech with the use of nominal phrases followed by pronouns" (p. 1019). These results indicate that children's gestures reveal a processing of "who did what to whom" as a first step toward narratives that are later expressed in speech. Thus, for both studies, the perspective expressed via gestures is considered to be a harbinger of the ability to express this perspective verbally. Once a particular aspect or a construction can be produced in speech, "children do not seem to rely on gesture to further expand" it (Demir & Goldin-Meadow, 2016, p. 277). However, even though these authors propose a facilitative role of gestures in the narrative process, they did not address the question of whether and how gestural behavior helps children to narrate.

## The facilitative effects of gestures for learning language

Studies providing empirical evidence for the facilitative effects of gestures on language learning (especially the acquisition of words) are reviewed below (see Table 12.1 for a summary).

### *Encouraging children to gesture*

In the spirit of studies providing evidence for gesture being a precursor to language, attempts have been made to support the language acquisition process by encouraging infants to gesture. Goodwyn, Acredolo, and Brown (2000) developed a system of symbolic gestures (as iconic gestures fixed in their form) that supported verbal utterances in a depictive way. Children of parents who applied this system to their communicative exchange on a daily basis had larger gestural repertoires than previously reported from spontaneous gesture use. In addition, when assessed for receptive and productive language, these children outperformed their peers in a control group. However, the difference in performance to the group in which parents were encouraged to provide more verbal input did not attain significance. A subsequent study by Kirk, Howlett, Pine, and Fletcher (2013) revealed that mothers trained in symbolic gestures were more responsive to their infants' nonverbal cues. The facilitative effect might thus reside in improving maternal responsiveness rather than in the children's cognitive skills. Nonetheless, Goodwyn et al. (2000) can be regarded as providing experimental evidence that encouraging children to gesture does not hinder language development. However, a beneficial long-term effect has not been shown so far (see Fitzpatrick, Thibert, Grandpierre, & Johnston, 2014, for a systematic review).

For pointing gestures, LeBarton and colleagues (2015) developed a training with the aim to elicit this type of nonverbal behavior in 17-month-old children when communicating with adults. The effects of the training study are remarkable, because the authors found increased gesture use and more different words in spontaneous interactions with their caregivers in the group of children trained with gestures compared to peers trained without gestures. Interestingly, this study also addresses the question of whether pointing gestures reflect infants' expressivity or serve as crucial communicative experiences that are beneficial for learning. The results speak in favor of children's gestures having a positive effect on their developing vocabulary.

In older children, fewer studies are known that focus particularly on children's language acquisition. However, Broaders and colleagues (2007) have successfully demonstrated that encouraging children to gesture aided their learning of mathematical concepts. Some possible explanations for the mechanisms are discussed below.

*Table 12.1* Summary of facilitative effects in word learning.

| | *Word comprehension* | | | *Word production* | | |
|---|---|---|---|---|---|---|
| *Word classes* | *Nouns* | *Verbs* | *Others* | *Nouns* | *Verbs* | *Others* |
| INFANCY (0–23 months) | | | | | | |
| Representational gestures (no differentiation) | Precursor effects: gestural use predicts larger vocabularies (Capirci et al., 1996; Rowe et al., 2008; Sansavini et al., 2010) | | | | | |
| Pointing gestures | Concurrent and longitudinal relation between gestural use and vocabulary in general (Colonnesi et al., 2010) | | | | | |
| | | | | Larger vocabularies after experimentally induced pointing gestures (LeBarton et al., 2015) | | |
| | Mapping effects assessed via gaze (Baldwin, 1993; Gliga & Csibra, 2009) | | | Precursor effects: gestural use predicts larger vocabularies (Beuker et al., 2013; Iverson & Goldin-Meadow, 2005; Ozçalişkan et al., 2016; Lüke et al., 2017 for the use of index-finger pointing)<br>Effects of own gestures facilitating learning (Lucca & Wilbourn, 2016) | | |
| Iconic gestures | | | | Enhancing effects (Goodwyn et al., 2000) | | |
| Conventional gestures | | | Gestural routines including conventional gestures predicted closed-class words (Kraljevi et al., 2014) | | | |

| | | | | | |
|---|---|---|---|---|---|
| TODDLERHOOD (24–48 months) | | | | | |
| Pointing gestures | Immediate recall effects (Booth et al., 2008); slow-mapping effects (Horst & Samuelson, 2008) | | | Slow mapping for words was less effective when trained with pointing gestures than when trained with iconic gestures (Capone Singleton, 2012) | |
| Iconic gestures | Slow-mapping effects (Vogt & Kauschke, 2017) | Immediate recall effects (Goodrich & Kam, 2009 Mumford & Kita, 2014)<br>Slow-mapping effects (Vogt & Kauschke, 2017) | Slow-mapping effects (McGregor et al., 2009) | Slow-mapping effects (Capone & McGregor, 2004; Capone Singleton, 2012; Kapalkova et al., 2016) | Following effects: The use of gestures increases after the use of first verbs (Ozçalişkan et al., 2014)<br>Slow-mapping effects (Vogt & Kauschke, 2017); effects at all times of learning (Kapalková et al., 2016) |
| Conventional gestures | Precursor to receptive language skills (Watt et al., 2006) | | | | |
| CHILDHOOD (48 months and up) | | | | | |
| Pointing gestures | | | | | |
| Iconic gestures | Immediate recall (Lüke & Ritterfield, 2014)<br>Hindering effects depending on complexity, conflicting gestures (McNeil et al., 2000) | | | Mnemonic effects (So et al., 2012)<br>Slow-mapping effects of words in L2 in children (Tellier, 2008) | Immediate recall and slow-mapping effects when imitating (Nooijer et al., 2013) or observing (Nooijer et al., 2014) gestures |
| | | | | Facilitative effects in L2 (Macedonia, 2014) | |

## *Presenting new words with the aid of gestures*

Various studies have confirmed the benefit of gestures for learning words of different classes. In the following, the effects for comprehension and production will be differentiated (see also Table 12.1).

### *Word comprehension*

The finding that infants follow a pointing gesture to attribute a novel word to a referent goes back to Baldwin (1993), who highlighted the value of pointing gestures as a cue used for the purpose of joint attention (see above). Another study by Gliga and Csibra (2009) demonstrated that 13-month-olds rely on the referential nature of pointing gestures. Thus, seeing a gesture evokes a particular state in infants in which they appreciate the fact that a learning content is being conveyed to them. There are thus several theories on why pointing gestures might help infants to comprehend novel words. One is about raising attention (see above). The other is about yielding a particular cognitive state that is linked to learning (Csibra, 2010). Although a lot of studies suggest that a pointing gesture can guide infants' attention more readily to the referent, few studies show that this clearly benefits word acquisition. This is in clear contrast to the benefits for toddlers.

Throughout toddlerhood, any arm gestures (pointing, touching, and manipulating) are more effective than sole eye gaze – as confirmed by Booth, McGregor, and Rohlfing (2008) when investigating learning to comprehend novel nouns in 28-month-olds. Long-term effects were reported for pointing gestures enhancing children's learning to comprehend new words (Horst & Samuelson, 2008). Accordingly, 24-month-olds were able to retain new nouns better when they were taught with pointing gestures than in a condition in which they had the opportunity to manipulate the object while the experimenter labeled it. In a further study, Axelsson and colleagues (2012) pursued the question why pointing and naming an object can be beneficial to children and introduced a condition in which attention was guided by the referent being illuminated instead of being pointed at. The authors were seeking to better understand whether it is the social interaction or the guidance of attention that leads to some benefits. Interestingly, children who saw the referent being illuminated retained words at greater than chance level compared to children who saw the referent introduced via a pointing gesture. The authors interpret their results in favor of attention-directing strategies being better for learning novel nouns. This finding corresponds to results obtained in a comprehensive study that not only analyzed parents' strategies for teaching children novel words but also tested the children's acquired word knowledge. With this study, Pereira, Smith, and Yu (2014) provide evidence strongly suggesting that the guidance of infants' attention to the referent is the key to successful learning. In naming events that were later associated with learning, parents attempted to minimize the competition for the reference. In addition, they increased the visibility of the referent before and after uttering the new word. Clearly, pointing gestures have the potential to increase visibility, but that seems to require a greater processing effort than just environmental cues such as illumination. This greater effort might comprise additional cognitive guidance, because pointing gestures also seem to alert infants to learning contents being conveyed and to evoke a cognitive stance going hand in hand with referential understanding (Gliga & Csibra, 2009).

Other word classes bring about challenges of a different nature for the learners; and hence, other gestural types than pointing might be more suitable for learning support. For example, there are only some cases in which actions can be pointed out. Moreover, Aussems and Kita (2017) argue that learning tasks in which children are taught verbs require the learner to focus

on action and to generalize the verbs across involved agents and objects. Nonetheless, 3- to 4-year-olds were shown to focus preferably on stable aspects, which "prevents children from generalizing action labels to novel events in which the same actions are shown, but the objects, actors, or instruments have changed" (Aussems & Kita, 2017, p. 1). Therefore, for these referents (actions or spatial locations), iconic gestures bear the potential to reflect some relevant aspects from a complex and transient event. At the same time, the reflection of some relevant aspects is also a selection that the authors consider to bring about a schematization of a perceived event, because "they guide children's attention to the actors' whole body, which created more opportunities to pick up person-specific information about the actors" (p. 10). In fact, a study with 3-year-olds by Mumford and Kita (2014) provides support for the idea of iconic gestures being related to the cognitive process of schematization, because children generalized the learned verbs according to the encoding aspects they perceived in the gesture: Those who learned the verb with the aid of a gesture expressing the manner of action (e.g., pushing) generalized manner aspects of actions; and those who learned with a gesture expressing change-of-state (e.g., breaking) used aspects of the end-state to generalize the newly learned verbs.

McGregor, Rohlfing, Bean, and Marschner (2009) introduced a long term aspect that is important for robust language learning when investigating the effects of training on understanding spatial prepositions. The training was based on either pictures or gestures depicting the target relation. This study followed a slow-mapping design, that is, not only the question of whether, immediately after the training, children can derive and apply the meaning of the preposition UNDER in order to assemble two objects together but also the question of whether this meaning would persist over a longer period of time. Crucially, the results showed that whereas immediate recall was better in the picture group, the slow-mapping gains for untrained material (which requires more robust semantic knowledge) were higher for children trained with gestures.

However, even though the positive effects dominate in the literature, there are some hints that gestures may also possess the potential to hinder word comprehension. For example, McNeil, Alibali, and Evans (2000) demonstrated that although 46- and 57-month-old children's comprehension can be scaffolded with reinforcing gestures that repeat the information provided in speech, conflicting gestures can hinder comprehension when provided to preschool children whose comprehension skills are limited.

## *Word production*

Infants' own use of the pointing gesture within an interaction as well as seeing it in a training situation was found to facilitate word production. An interesting approach is reported by Lucca and Wilbourn (2018), who investigated the interactive process of learning and looked at how children's own performance in pointing gestures can enhance their subsequent learning. Sixteen-month-olds – but not 12-month-olds – were observed to map nouns more readily to objects if "they had first pointed towards those objects than if they had referenced those objects via other communicative behaviors, such as reaching or gaze alternation" (p. 1). The authors interpreted the results in terms of infants' readiness (and desire) to learn that is signaled by their pointing. This approach is in line with learning theories highlighting the active role of infants in learning (e.g., Begus, Gliga, & Southgate, 2014). Accordingly, offering a learning content in response to infants' communicative gestures led to superior learning.

For nouns specifically, Capone and McGregor (2004) conducted a study in which 28-month-old toddlers had to comprehend and retrieve novel items when trained with and without a gesture. Less scaffolding was necessary in the groups trained with gestures. The

authors concluded that mapping conditions were semantically richer than the nonmapping condition given to the control group, because providing gestures resulted in more information about relevant aspects of the referent. Goodrich and Hudson Kam (2009) offer a similar explanation for their results on children's learning of novel verbs' meanings from iconic gestures. Capone Singleton (2012) conducted an interesting study pitting the benefits of iconic gestures against deictic gestures with 32-month-olds in a within-subject design. In this slow-mapping study that trained children with novel nouns, learning results obtained in the pointing condition never outperformed performance in the iconic gesture condition. She interpreted the results favoring iconic gestures as indicating that they were "particularly amenable to drawing attention to the semantic features that define an object category because gesture exploits the visual modality" (p. 290).

For older children, better mnemonic effects have been reported when gestures were included in word encoding. This was the case in the study by So and colleagues (2012; see also Llanes-Coromina, Vilà-Giménez, Kushch, Borras-Comes, & Prieto, 2018) examining the ability to recall words after both 4- and 5-year-olds and adults had encoded them with or without gestures. For children, only iconic, and for the adults, both iconic and beat gestures (roughly defined as rhythmic movements of the arms that are produced together with prominent prosody) aided their recall performance. This finding is in line with Tellier's (2008) study in which children learned words from a second language. She argued that a training in which children at the mean age of 5 years and 5 months had to reproduce some gestures left "a richer trace in memory" (p. 219) than a training in which they learned mixed words (mostly nouns but also a few verbs) from pictures.

De Nooijer and colleagues (2013, 2014) observed that imitation of gestures either during learning or during an immediate recall test can positively influence 9- and 10-year-old children's immediate and delayed recall of verbs. Interestingly, the authors argued that the effect depends on the verb type. Accordingly, the memories of verbs that refer to object manipulation were better scaffolded by the imitation of gestures than abstract verbs (de Nooijer et al., 2013). A further study also revealed that children whose language skills were poorer than their peers' did not benefit from the enactment (de Nooijer et al., 2014). This relationship of iconic gestures to language skills is interesting and in line with Özçalışkan and colleagues' finding (2014) revealing that young children (aged 14 to 34 months) produced their first iconic gestures 6 months later than their first verbs. Together, the results open up the possibility that iconic gestures reflect a schematization that takes place via the use of language and especially when expressing actions (as suggested by Mumford & Kita, 2014). Thus, the benefits of iconic gestures for learning to produce words can vary across learning contexts and learners.

Although this review focuses on the acquisition of words (see Table 12.1), there is evidence suggesting that the facilitative effects extend toward comprehensive linguistic skills. Kirk, Pine, and Ryder (2011) demonstrated that pragmatic comprehension is enhanced when children see gestures in addition to inferences that could be drawn from the verbal content presented. Along the same lines, stories told with beat gestures were comprehended better by children than stories without beat gestures (Llanes-Coromina et al., 2018).

## *Gestures in children with developmental language disorders*

As mentioned above, the benefits of gestures seem to depend on children's language skills (de Nooijer et al., 2014). A study of the population of children with developmental language disorders (DLD) (see also Chapter 18, this volume) helps to pursue this premise further. Those children's language can be characterized by reduced expressive and/or productive language and

literacy skills. These deficits persist throughout school age and into adolescence and result in diminished chances of educational attainment and, thus, economic success.

Because early intervention is highly effective, some investigators have exploited early gestural behavior in children as a window to later language development (see, e.g., Lüke, Grimminger, et al., 2017, for the most recent work) and as a possible way to identify late talkers – that is, young children in the lowest 10 percent for expressive vocabulary who produce fewer than 50 words and barely combine them into two-word utterances (Capone & McGregor, 2004). Although the majority of late talkers will catch up by 5 and 7 years, they remain at risk for reduced language and literacy skills.

Different studies investigating the benefits of gestures for children who are delayed in their language acquisition have reported a higher rate of gesturing behavior, although there are also some studies in which no such differences were found (Blake, Myszczyszyn, Jokel, & Bebiroglu, 2008). More recently, Lavelli and Majorano (2016) studied children at the age of 3.5 to 5.5 years during a picture-naming task and found that children with delayed language learning did not show the preference for spoken answers characteristic of their typically developing peers. Instead, and also in contrast to age-matched children, they produced more representational gestures with which they both reinforced and added to the verbal content, especially when the target words were verbs, adjectives, and location adverbs in comparison to nouns. Whereas the system of language-gesture integration in this particular group of children was observed to be similar to a typical population (Blake et al., 2008), many investigators have suggested that gestures might facilitate access to the lexicon in children with DLD. Following this premise, Vogt and Kauschke (2017) investigated whether children with delayed language development at the age of 4.5 years benefit particularly from gestures during a long-term word learning task. They found that this group of children, as well as the control group of typically developing children, benefited from a presentation in which the new word was accompanied by an iconic gesture, in contrast to attention-directing or arbitrary gestures. Thus, no particular advantage for this group of children with DLD became evident.

Lavelli, Barachetti, and Florit (2015) have presented an insightful contribution to the role of gestures that follows an interactive approach. They investigated the gestural behavior of both children and their caregivers during a book-reading situation. A sequential analysis comparing maternal and children's behaviors revealed that children with DLD did not just use significantly more representational gestures than their typically developing peers. Crucially, in comparison to typically developing children, children with DLD were found to be more sensitive to their mothers' co-speech gestures; this sensitivity was revealed by children following the mothers' gestural behaviors with a high probability by initiating verbal behavior or giving adequate answers. This was not the case in the other control groups matched for age and language skills. This finding attests to a great sensitivity to gestures among children with DLD.

In the literature, the higher frequencies of gestures in children with DLD in comparison to their peers are commonly explained by the compensatory nature of gestures. More specifically, Capone and McGregor (2004) have suggested that children with DLD use gestures to compensate for their expressive language deficits. However, results reported by Lavelli and Majorano (2016, p. 793) cast some doubt on this, suggesting that children with DLD might actually rely more on a different communicative repertoire, "one in which spoken modalities are not clearly preferred to gestures". This view is supported by recent findings on younger children revealing that whereas typically developing children show a clear focus on verbal behavior consisting of a decrease of points and more words produced without gestures at the end of their second year of life, in children who are delayed in their language development, a significant increase in pointing gestures can be observed (Lüke, Ritterfeld, et al., 2017).

## Some explanations for the facilitative effects of gestures

As reviewed above, a growing body of research demonstrates the beneficial role of gestures for language learning at different ages and in different groups of children. Below, explanations for this facilitative effect are offered.

### *Gestures matter to the speaker*

A first explanation targets the cognitive effects that gestures imply for processing language. According to the embodied view on cognition, the activity of gesturing reflects a connection between language and the motor system (Hostetter & Alibali, 2010; Volterra, Capirci, Caselli, Rinaldi, & Sparaci, 2017). In research on adults, this connection has been demonstrated impressively in studies showing that producing meaningful movements seems to make things easier for speakers' working memory, because they are able to remember more about the learning content than when they produce meaningless movements (Cook, Yip, & Goldin-Meadow, 2012). Focusing on children's language acquisition, Iverson (2010) has provided a comprehensive review of findings advocating a relationship between motor and language development. Studies such as that by Ejiri and Masataka (2001) or Iverson and Fagan (2004) revealed that infants produce an increasing number of rhythmic motor movements just before the onset of canonical babbling (that requires a reduplication of syllables). In infants studied by Ejiri and Masataka, these rhythmic actions decreased once canonical babbling emerged. The authors interpreted the motor actions as "helping infants learn the articulatory skills required to produce" canonical babbling (ibid., p. 47). In a larger sample of 6- to 9-month-olds, Iverson and Fagan (2004) recorded an increase in vocal-motor coordination that was greater for the arm (specifically the right arm) than for other body parts. Consonant-vowel combinations (which are considered speech-like in the literature) were more likely to occur with rhythmic movement than without it. The authors viewed this coordination as a precursor to the coordinated gesture-speech system that is stable and present even in congenitally blind persons (Iverson & Goldin-Meadow, 1998).

The co-occurrence of motor and language skills provides infants with opportunities to "practice skills relevant to language acquisition before they are recruited for that purpose" (Iverson, 2010, p. 254). Another value lies in broadening the exploration space: If actions co-occur in a systematic manner, they convey new meanings that are then transported to the environment. Accordingly, children can receive informative responses (see the facilitative route of learning below). Iverson (2010, p. 255), however, limits the necessity of motor development for language acquisition: "there is undoubtedly a wide variety of alternative means" that can account for the gains of motor skills. This speaks to the resilience of the language learning process (Goldin-Meadow, 2015).

A further cognitive explanation has been proposed by Kita, Alibali, and Chu (2017). In their framework, the authors concluded that representational gestures "activate, manipulate, package and explore spatio-motoric information for speaking and thinking" (p. 245). The proposition here is that a gesture creates the possibility to wrap up a package (i.e., a selection) of features that are relevant to the task. Although the relevant features are linked tightly to practical actions and object manipulations, they are more abstract than these. This "schematization" is an efficient and flexible way of representing something (Kita et al., 2017, p. 255), because it aids in stripping away other elements of rich representations that are not relevant for this task. This "packaging" already becomes visible in toddlers, as confirmed in a longitudinal study that observed children's use of iconic gestures from the age of 12 to 36 months (Furman, Küntay, & Özyürek, 2014). Interestingly, this study evidenced a strong relation between children's gestures and language-specific

verbs, suggesting that "the development of representation in iconic gestures is not universal but can be modulated by certain language-specific factors" (p. 631).

## *Gestures matter to the listener*

Early in a child's development, any kind of body movement can be considered as a communicative signal that is taken up by caregivers (Rohlfing et al., 2017). In the course of the conventionalization process, caregivers guide children to those means that are most appropriate in their communication. For deictic gestures, the process of conventionalization has been described repeatedly (e.g., Marcos et al., 2003). For iconic gestures, in contrast, the process is not well understood. Streeck (2008) has proposed the term "depictive practices" to refer to the fact that some gestures are "acts of showing the addressee by movements and postures of the hand what something *looks like* or *is like*" (p. 289). Yet other gestures can also form a conceptual relation to thoughts – what Streeck (2008) call *ceiving gestures* because they indicate something about the speaker's concept or cognitive state. However, the question is whether these gestures can be perceived by listeners. It has to be mentioned that with the exception of Heller and Rohlfing (2015), developmental studies have not yet followed up Streeck's differentiation. Instead, they consider all representational gestures together. Demir and Goldin-Meadow (2016) have reviewed a number of studies showing that in addition to speech, listeners also regard the information conveyed in gestures. For children, Goldin-Meadow and Sandhofer (1999) have provided important evidence suggesting that when children at the age of 5 to 8 years gestured, adults listening to their explanations of a Piagetian conservation task were able "to glean substantive information from the children's gestures" – information that was unique to the gestural modality. Accordingly, Goldin-Meadow and Wagner (2005) have argued in favor of a facilitative route of learning: When listeners extract information from the speaker's gesture, they can adjust their responses accordingly, and listeners will then benefit from the adjusted input (Goldin-Meadow, Goodrich, Sauer, & Iverson, 2007; Dimitrova, Özçalışkan, & Adamson, 2016). Together, this route (from speaker's gestures to listener's scaffolding adjustments) provides an effective support for learning. As the child's knowledge expands, gestures can also signal the consistency of the learner's knowledge and thus also a transition in the learning state (Church & Goldin-Meadow, 1986, p. 67) to which teachers seem sensitive and to which they can respond (Broaders et al., 2007).

Supporting the facilitative route of learning, Lavelli and colleagues (2015) revealed that parents adjust to their child's linguistic skills, because mothers of children with DLD gestured more than mothers of typically developing children. However, in contrast to this, Lüke, Ritterfeld, et al. (2017) found no difference in either overall gestural or verbal behavior when analyzing caregivers of younger children at the age of 12 and 18 months with typical and delayed language acquisition. Overall, gesture-speech combinations in input to young infants can be characterized as gestures reinforcing verbal utterances (Grimminger et al., 2010; Iverson et al., 1999; Rader & Zukow-Goldring, 2010). For a typical population, Özçalişkan and Goldin-Meadow (2005) revealed a rather constant frequency of gesture-speech combinations in the course of children's language development, suggesting that the changing relation between gesture and speech observed in children "cannot be traced back to the gestural input the children receive" (p. 481). Hence, the facilitative route of learning is not straightforward. In addition to studies evidencing rather constant instead of adaptive behavior of caregivers, Goldin-Meadow and Sandhofer (1999) found that gestures hinder listening if they convey information different from that in speech. Obviously, factors such as the complexity of the task as well as the message can influence the listener's behavior.

### *Gestures elicit communication*

Building on the aspects mentioned above, one could argue that gestural behavior not only matters to the listeners but also elicits further communication. This point was already raised when addressing facilitative effects of gestures on word production. It is relevant because it emphasizes that especially young children can enter communication as active participants in an exchange. This is in line with recent research (Begus et al., 2014; Lucca & Wilbourn, 2018) demonstrating that through pointing, infants can elicit caregivers' responses that bring about superior learning. These findings suggest that it is important not only to follow a child's interest and thus readiness to learn, but also to engage jointly in a task, let the child play a role in it, and thereby to truly maintain this readiness. It is likely that not only the modified input per se is crucial, but also the way the interaction changes and whether the child receives the role of co-constructing an event during its course. For example, in a longitudinal study, Goldin-Meadow and colleagues (2007) found that mothers of younger children translated their child's gestures into words. They interpreted their findings as indicating that the mothers were providing their children with a verbal model of gestural information for learning language. However, another possibility is that with the "translations" of gestures, caregivers take up on them, thus letting the child play a contributing role to the conversation that unfolds toward a topic that is co-constructed – an ability employed equally by parents of typically developing children as well as those with autism and Down syndrome (Dimitrova et al., 2016). Thus, it is the ability to not only notice information in gestures (Goldin-Meadow et al., 2007) but also react to them and make them a part of an unfolding conversation (Rohlfing et al., 2017) that is important.

## Summary

While many types of gestures occur in an interaction, studies on language learning have focused on the facilitative effects of representational gestures that are performed with the arms and synchronized tightly with speech. Their facilitative effect consists in the possibility for infants not only to play an active role in early interactions but also to master the synchronization with the partner and, thus, to benefit from further, well-tailored information. In the long term, such interactions provide a rich learning environment in which learners are given the opportunity to wrap up a package of features that are necessary to remember individual words through reference to an object or event. This "packaging" is an efficient and flexible way of representing events and seems to be modulated by certain language-specific factors. Although this review has focused on word learning, these effects extend to narrative skills as well.

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# 13
# PRAGMATIC DEVELOPMENT
## Learning to use language to communicate

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### Introduction

When learning to communicate efficiently through language, children rely on a set of developing cognitive abilities which are often described as part of our *pragmatic competence*. These include the abilities to engage in joint attention, to draw inferences, to attribute mental states and to integrate contextual information from a variety of sources. The last couple of decades have seen an increasing interest in the development of such pragmatic abilities, due to the recognition of their foundational role for language acquisition more generally (Baldwin, 1993; P. Bloom, 2000; E. V. Clark, 2016; Ifantidou & Matsui, 2013; Matthews, 2014; Tomasello, 2003, 2008; Zufferey, 2015). This chapter presents an introduction to some key topics in research on the development of pragmatic abilities and their role in language acquisition. These include pre-verbal communication, pragmatic aspects of word learning, reference and non-literal uses of language, focusing on implicature and figurative language.

### *Defining pragmatics*

A traditional definition of pragmatics is the study of language use (Y. Huang, 2007; Levinson, 1983; Morris, 1938). This broad description refers to both cognitive and socio-cultural perspectives, and covers a wide variety of approaches, including indexical semantics, dynamic semantics, speech act theory, conversation analysis, corpus pragmatics, cognitive and experimental pragmatics, intercultural pragmatics, sociolinguistics and several others. This heterogeneity is what Ariel (2010) has called "big-tent pragmatics", a field delineated more by a set of topics that are considered to be the primary focus of investigation than by any explicit criteria defining what pragmatics is.

A narrower definition, which will be used throughout this chapter, delimits pragmatics to the study of how hearers bridge the gap between underspecified communicative signals (typically in the form of linguistic utterances, but also gestures, facial expressions, etc.) and full-fledged speaker meanings on the basis of contextual factors (Noveck & Sperber, 2004; Sperber & Wilson, 1986/1995). On the production side, pragmatics studies how speakers tailor their utterances to the communicative needs of their interlocutors and the utterance-situation, in line with their preferences and abilities (Sperber & Wilson, 1986/1995). This understanding of the domain of

pragmatics, whose main focus is the cognitive underpinnings of the interpretation and production of communicative signals, has its roots in the philosopher Paul Grice's (1975/1989) theory of conversation and his original insight that inference plays an important role in human communication.[1] While for Grice this role was limited to the derivation of the implicit content of an utterance, that is, communicated meanings that are implied by a speaker (*implicatures*), modern cognitive pragmatic theories treat the interpretation of the explicit content of an utterance (*what is said*) as also relying on pragmatic inference (Carston, 2002; Horn, 2007; Levinson, 2000; Recanati, 2010; Sperber & Wilson, 1986/1995). For instance, if a speaker utters *It's late* in response to an invitation to go for a drink, one possible implicature might be that the speaker thinks it's too late to go out for a drink and thereby rejects the invitation. However, in a context where the speaker and hearer have been at the office together all day, another possible implicature might be that the speaker thinks it's late enough to stop working and go for a drink. In both contexts, pragmatic inference is required to determine the explicit content of the utterance, more specifically the speaker's intention by use of the adjective *late*, as well as the implicit content to be derived from it.[2]

A key debate in the cognitive pragmatic literature, far from settled, concerns the division of labor between linguistic decoding (*semantics*) and inference (*pragmatics*) in the interpretation of verbal utterances. In this chapter I will not take a stance on this debate on the semantics-pragmatics divide beyond assuming, along with most modern theoretical pragmatic approaches, that pragmatic inference plays a major role in verbal comprehension, in deriving both explicit and implicit utterance content. I will follow Ariel, relevance theorists and others (Ariel, 2010; Sperber, 1994; Sperber & Wilson, 1986/1995) in delimiting the scope of pragmatics to inferred meanings as opposed to coded (i.e., conventional) meanings – which are taken to belong to the domain of semantics – showing at the same time how the acquisition of coded meanings crucially relies on the child's developing pragmatic inferential abilities.

## *Developmental pragmatics*

Although it is something we as communicators do both effortlessly and unconsciously most of the time in everyday communication, bridging the gap between sentence meanings and fully fledged speaker meanings is no small achievement. In interpreting both verbal and non-verbal utterances, hearers draw on a range of knowledge and abilities. As the example above showed, arriving at the speaker-intended meaning of even a simple utterance such as *It's late* cannot be achieved via a mere decoding of the linguistic material but requires taking a set of contextual assumptions into account and using these as premises in inferring the speaker-intended meaning. How do children acquire the ability to do this?

Developmental pragmatics is concerned with how children acquire the ability to use language for communicative purposes, enabling them to express their own intentions and draw inferences about the intentions of others. Pragmatic development has traditionally been studied in two disciplines: developmental psychology and linguistics, and mainly by researchers interested in first language acquisition. The earliest studies date back to the late 1970s (Bates, 1976; Ochs & Schieffelin, 1979), and the field has been rapidly growing over the past couple of decades, with its focus shifting from the acquisition of social skills (Ninio & Snow, 1996) to the developing cognitive abilities underlying language use and understanding (E. V. Clark, 2016; Ifantidou & Matsui, 2013; Matthews, 2014; Zufferey, 2015). Recently, theoretical pragmaticists have become interested in pragmatic development due to its potential to inform theoretical debates about utterance interpretation in adults. The large and growing experimental literature on the acquisition of so-called *scalar implicatures*, which I will introduce later in this chapter, is a case in point.

The growing interest in the development of communicative abilities is reflected in current theories about the origin of language and the transmission of cultural knowledge. For instance, Tomasello (2008) claims that our capacity for language is rooted in a uniquely human cooperative activity which relies on *shared intentionality* (Tomasello, Carpenter, Call, Behne, & Moll, 2005). The cognitive skills for creating joint attention and intentions, and the social motivations for helping and sharing are called "the cooperative infrastructure of human communication" (Tomasello, 2008, p. 7), and it is only within this context that arbitrary linguistic conventions could have come into existence. The hypothesis carries over to ontogeny, where the claim is that language is acquired against an infrastructure of shared intentionality, with pre-linguistic gestures emerging before language. Communication is also a central feature of Pedagogy Theory (Csibra, 2010; Csibra & Gergely, 2009, 2011), which focuses on the transmission of cultural knowledge. The claim is that humans are specifically adapted to acquire generic knowledge from ostensive communication, that is, communication which involves the use of a stimulus intended to make something manifest to an audience, even before the emergence of language. Further, in his theory of the origins of human sociality, Levinson (2006) claims that all human languages, although they differ in form across cultures, have in common that they are grounded in universal properties of human interaction such as speech acts and turn-taking.

In this chapter, I will provide an introduction to the currently most active research areas in developmental pragmatics. Being a relatively young field, there is still a lot of ground to cover before we have the full picture, but the topics presented here go some way in providing an overview of children's developing pragmatic abilities. What is perhaps most striking about pragmatic development – and something for which we still need an overall explanation – is the wealth of evidence showing, on the one hand, how pre-linguistic children already possess quite sophisticated pragmatic abilities, and, on the other hand, the pragmatic difficulties they seem to experience with certain uses of language during the preschool years. While my perspective will be mainly a cognitive one, socio-cultural factors such as the nature of interpersonal relations between speakers and hearers, social norms governing language use, cross-linguistic and cross-cultural differences in language use and social interaction obviously also play an important role in the development of communicative and linguistic competence.

## Pre-verbal communication

Before they utter their first words, human infants have already reached several fundamental pragmatic milestones (for an overview, see Stephens & Matthews, 2014). From very early on, infants are able to detect infant-directed ostensive communication in the form of eye contact, speech and contingency (Csibra, 2010; Csibra & Gergely, 2009; Tauzin & Gergely, 2018). Eye contact is a central feature of human communication and functions to establish communicative links between interlocutors, and to confirm the addressee of a message. From birth, human infants are able to discriminate between direct and averted gaze, preferring to look at faces that appear to make eye contact with them (Farroni, Csibra, Simion, & Johnson, 2002). This has been interpreted as suggesting that human infants are born prepared to detect socially, and specifically communicatively, relevant information (Csibra, 2010).

Cross-linguistically and cross-culturally, caregivers tend to use a special intonation pattern when speaking to infants, which serves to make it manifest that the infant is the addressee of the speech. Such *infant-directed speech* (or "motherese") is characterized by the use of higher pitch, slower tempo, shorter utterances and longer pauses between utterances compared with speech directed to adults (Fernald et al., 1989), and infants have been shown to prefer

infant-directed speech over adult-directed speech already from birth (Cooper & Aslin, 1990). By 5 months of age, infants can discriminate affective vocalizations in infant-directed speech, responding more often with a smile to positive speech and with negative affect to negative speech (Fernald, 1993). This suggests some early understanding of speakers' communicative intentions.

Contingency in the form of turn-taking patterns is another feature of human communication with strong universal tendencies (Stivers et al., 2009), and infants as young as 2 months are sensitive to social behavior that is temporally contingent on their own actions, preferring contingent responses to random stimulation (Murray & Trevarthen, 1985). In the period from birth to 9 months, infants take part in communication that is essentially *dyadic*, involving interactions with their caregivers (Snow, 1977). The caregiver plays an important role in scaffolding these interactions by seeking out and responding to turn-taking sequences from infants' actions (K. Bloom, 1975), even to involuntary ones such as burps, yawns and sneezes (Snow, 1977), and by responding verbally to changes in infants' behavior (Henning, Striano, & Lieven, 2005). These early interactions between mothers and infants typically involve face-to-face play situations with coordinated gazing, smiling and vocalizing. Infants become gradually attuned to the conventions of these scaffolding interactions, in particular to their timing and structure (Rochat, Querido, & Striano, 1999). Due to its resemblance to the turn-taking pattern of normal human communication, this synchronization of behavior in the form of contingent responsivity has been called "proto-conversation" (Bateson, 1975, 1979). While such early turn-taking sequences are based on temporal contiguity, they may provide the foundation for the emergence of semantic contingency, which links individual turns to each other through meaning, later on in development (Casillas, 2014). It seems clear, then, that young infants have not only an early motivation to communicate but also some early comprehension of intentional communicative behavior directed at them, and that these abilities are already present or emerging during the first few months of life.

Around 9 months of age, infants start to engage in *triadic* communication, extending the interaction from the infant-caregiver dyad to external objects and situations. The infant is now able to participate in episodes of *joint* or *shared attention* in which the infant and caregiver simultaneously attend to the same thing, and are mutually aware that they are doing so (Bakeman & Adamson, 1984; Scaife & Bruner, 1975; Tomasello, 1995). In an early longitudinal observational study of infants aged 6–18 months, Bakeman and Adamson (1984) found that infants' joint intentional activity increased with age, and that infants spent more time engaging in joint attention with their mothers, who were supporting or "scaffolding" their infants' early attempts to embed objects in social interactions, than with their unskilled peers. Engaging in acts of joint attention requires an understanding of the intentions of others (Tomasello & Carpenter, 2007), and more specifically their communicative intentions (P. Bloom, 2000; Tomasello, 1998). This is seen as providing the foundation for the emergence of pre-linguistic communicative gestures between 9 and 12 months of age (Bates, Camaioni, & Volterra, 1975; Butterworth, 2003) and the development of expressive language in the second year of life (Baldwin, 1995; Tomasello, 2003, 2008).

The pre-verbal stage can be seen as a stage of "pure pragmatics" (Matthews, 2014), where communication proceeds without an expressive lexicon and a grammar.[3] In responding to joint attention, infants rely on eye gaze and gestures (Corkum & Moore, 1995), and in initiating acts of joint attention they may use gestures such as pointing, showing and reaching to direct the attention of their caregivers to external objects (Bates, 1979; Carpenter, Nagell, & Tomasello, 1998). In the vast majority of cases, pre-linguistic gestures emerge before children start using

any referential language (Carpenter et al., 1998). On the basis of a repertoire of gestures, pre-linguistic infants are able to communicate a range of different intentions (Acredolo & Goodwyn, 1988; Blake,Vitale, Osborne, & Olshansky, 2005; Iverson, Capirci, & Caselli, 1994). Hands in the air may suggest "lift me up", a big smile in response to an offer of something attractive may be interpreted as "I want it", vigorous arm waving in response to the same offer as "I don't want it", and an open mouth as "Feed me".

The pointing gesture, emerging around 11 months (Butterworth, 2003), has been attributed a special role in establishing the joint attention "infrastructure" for the later emergence of language (Tomasello, 2008). Research on infant pointing suggests that it serves three general classes of communicative intention or motivation, which are similar to the way adults use pointing (Tomasello, Carpenter, & Liszkowski, 2007). Infants point to share emotions and attitudes about referents. In one experiment, 12-month-old infants did not prolong or repeat their pointing when the adult expressed disinterest ("Uh . . .") compared to when they expressed interest ("Cool!") in the referent (Liszkowski, Carpenter, & Tomasello, 2007). Infants also point to inform others of useful or interesting things. Liszkowski, Carpenter, Striano, and Tomasello (2006) found that 12-month-old infants pointed more often at an object whose location an adult did not know than when the adult knew its location, suggesting that already at this age infants take interlocutors' knowledge states into account in their production of gestures, and point to provide information for others. Finally, infants point to request help from others in attaining their goals (Bates et al., 1975; Camaioni, 1993). For instance, they may point to the location of a desired object in order to get the adults to bring them the object in question.

A growing body of research suggests that such pre-linguistic gestures not only predate the emergence of language but may also play an important role in language development (Blake et al., 2005; Carpenter et al., 1998; Goodwyn, Acredolo, & Brown, 2000; Iverson et al., 1994; Iverson & Goldin-Meadow, 2005; Özçalışkan & Goldin-Meadow, 2005, 2006). The age of onset of communicative pointing has been shown to be related to receptive vocabulary at 14 months (Butterworth & Morissette, 1996) and receptive and expressive vocabulary at 24 months (Desrochers, Morissette, & Ricard, 1995). In a cross-cultural comparison of communicative gestures in infants aged 9 to 15 months, Blake,Vitale, Osbourne, and Olshansky (2005) found that frequency of gesturing, in particular pointing, was positively correlated with receptive vocabulary at 15 months and 3 years. Furthermore, studies have shown that changes in infants' gestures predict changes in language (Iverson & Goldin-Meadow, 2005; Özçalışkan & Goldin-Meadow, 2005). For instance, in a longitudinal study of children aged 10 to 24 months, Iverson and Goldin-Meadow (2005) found that many of the meanings children conveyed initially in the gestural modality later emerged in their verbal lexicon (e.g., a point to "cookie" predicted the emergence of *cookie* shortly after). In another study, Özçalışkan and Goldin-Meadow (2005) found that for children in the one-word stage, the age at which they started supplementing their words with gestures to convey complex meanings (e.g., *want* + point at toy) reliably predicted the age at which they started producing two-word utterances. This tight relation between gesture and language in development supports the view that socio-pragmatic factors underlie the emergence of both.

Taken together, the evidence from studies of pre-verbal communication suggests that already at this stage children possess and develop quite sophisticated pragmatic abilities, which allow them to engage in acts of joint attention and referential communication with their caregivers by use of eye gaze and a repertoire of gestures. Below we look at how this early pragmatic competence provides the foundation for the acquisition of word meanings and referential communication by use of language in the preschool years.

## Reference

In the context of communication, reference has to do with the way linguistic expressions and other communicative signals relate to the things we use them to communicate about, and is a topic with a long history in philosophy of language and linguistics (for an overview, see Abbott, 2010). The acquisition of reference, that is, how children learn to appropriately assign contextual reference to a word, gesture or phrase, and to appropriately use referential expressions in communication, is a central topic in developmental pragmatics (for a review, see Graf & Davies, 2014).

In this section we look more closely at pragmatic aspects of word learning, that is, the pragmatic abilities or mechanisms required for acquiring conventional (i.e., coded), context-independent mappings between word forms and meanings. We then look at the broader phenomenon of referential communication, more specifically the development of the appropriate use and understanding of referential expressions in context (which can be verbal or non-verbal).

### *Pragmatic aspects of word learning*

How do young children learn the meaning of words? To explain this, different theories have evoked either general learning mechanisms enabling children to associate salient sounds with salient objects or events (McMurray, Horst, & Samuelson, 2012; Sloutsky, Hyungwook, & Dennis, 2017; Smith, 2000), a set of biases or constraints specifically aimed at word learning (the whole object bias: Hollich & Golinkoff, 2007; the shape bias: Landau, Smith, & Jones, 1988; the mutual exclusivity bias: Markman & Wachtel, 1988) or social-pragmatic abilities allowing children to acquire word meanings through understanding of speakers' referential intentions (Baldwin & Moses, 2001; P. Bloom, 2000; E.V. Clark, 1993; Tomasello, 2003). While researchers agree that all these factors are in some way likely to be involved in word learning, they focus on different processes as the main driving force underlying children's acquisition. A growing number of studies emphasize the crucial role that socio-pragmatic factors play in the acquisition of word meanings.

When children utter their first words between 14 and 18 months of age (Tomasello, 2003), they have already become sophisticated non-verbal communicators, using deictic, iconic and symbolic gestures, facial expressions and vocalizations – both alone and in combination – to communicate with their caregivers (Acredolo & Goodwyn, 1988; Bates et al., 1975; Messinger & Fogel, 1998). As discussed above, such pre-linguistic communication is made possible through infants' developing ability to convey and understand communicative intentions against a background of "shared intentionality" (Tomasello & Carpenter, 2007). Social-pragmatic theories of word learning assume that joint attention and intention reading (theory of mind) are foundational processes for the acquisition of the lexicon as well (P. Bloom, 2000; Tomasello, 2003, 2008).

#### *Eye gaze and gesture as input to word learning*

Communication by adults is a crucial source of information for infants when learning the meaning of new words. Adults provide information about word meanings through their use of language, gesture and behavior. Children use such "pragmatic information" to infer the speaker's intention in using a word that is new to them (see Grassmann, 2014, for an overview).

An early source of information about word meanings is the speaker's gaze, and from the age of 12 months children rely on the speaker's gaze direction to identify the referent of a novel word (Baldwin, 1991, 1993; Baldwin et al., 1996; Yurovsky & Frank, 2017). For instance, Baldwin and colleagues (1996) found that 18-month-olds were able to learn novel labels for unfamiliar objects when they saw the speaker looking at the object, but not when the speaker was outside their view. However, children with autism spectrum disorder (ASD), whose joint attention abilities are typically impaired (e.g., Mundy, Sigman, Ungerer, & Sherman, 1986), tend to rely on their own focus of attention rather than the direction of the speaker's gaze in assigning novel words to novel objects, leading to mapping errors (Baron-Cohen, Baldwin, & Crowson, 1997). Further, the key role played by joint attention in word learning is also evident by the fact that the amount of time children spend in joint attentional interactions with their caregivers, established through gaze following and pointing, is positively correlated with their vocabulary size (Brooks & Meltzoff, 2008; Carpenter et al., 1998; Tomasello & Todd, 1983).

Another source of information that young children rely on to infer new word meanings is the speaker's use of deictic and iconic gestures. Such gestures are used by adults to support children in their construction of meanings for new labels, and the presence of gestural cues has been shown to facilitate word learning (Booth, McGregor, & Rohlfing, 2008; Capone Singleton, 2012; O'Neill, Topolovec, & Stern-Cavalcante, 2002). Already from the age of 13 months, infants expect that when pointing and naming co-occur they refer to the same thing. For instance, Gliga and Csibra (2009) showed infants video clips of an actress naming a hidden object while indicating its location using gestures. Infants looked longer at the named object when it was revealed in another location than that indicated by the actress's gestures, suggesting that they expected the name and the gestures to co-refer. From around 18 months children start relying on pointing in word learning (Briganti & Cohen, 2011). Booth, McGregor, and Rohlfing (2008) demonstrated that 2-year-olds' word learning was improved when speakers not only gazed at but simultaneously pointed at the novel object. Another study by Goodrich and Hudson Kam (2009) showed that already at age 2, children can use action information contained in an iconic gesture to disambiguate novel verb meanings. In combination with speech, adults' gestures serve to initiate and maintain joint attention on an object with children, and to provide additional information about object parts, properties, actions and functions (E.V. Clark & Estigarribia, 2011). There is mounting evidence that such "pragmatic directions" play an important role in language learning.

## *Reliance on speakers' intentions*

More generally, there is much evidence that the ability to infer speakers' intentions guides children in their label-object mappings. For instance, Tomasello and Barton (1994) found that 2-year-old children learned novel verbs from intentional but not from accidental actions. Tomasello, Strosberg, and Akhtar (1996) found that in the context of a finding game, children aged 18 months learned the novel word for an object that the speaker had announced her intention to find ("Let's find the modi"), ignoring objects that the speaker had rejected during her search.

Children also take speakers' prior knowledge into account when mapping novel words to novel objects. Akhtar, Carpenter, and Tomasello (1996) demonstrated that when presented with a novel word and three novel objects, 2-year-old children take the novel word to refer to the object that is new to the speaker, ignoring the two they had seen her playing with earlier. In other words, children are sensitive to what is new from the speaker's point of view and are able to make use of this information in inferring the referent of the novel word (see, however, Horst,

Samuelson, Kucker, and McMurray, 2011, for a discussion of a novelty bias in children's referent selection). Furthermore, a large body of research has shown that children track speakers' mental states (e.g., whether the speaker is inaccurate or ignorant, or has limited or full knowledge) in learning new words (Birch & Bloom, 2002; Birch, Vauthier, & Bloom, 2008; Jaswal & Neely, 2006; Koenig, Clément, & Harris, 2004; Koenig & Harris, 2005; Koenig & Woodward, 2010; Papafragou, Fairchild, Cohen, & Friedberg, 2017; Sabbagh & Baldwin, 2001; Sabbagh & Shafman, 2009; Scofield & Behrend, 2008; Southgate, Chevallier, & Csibra, 2010). For instance, in the study by Koenig, Clement, and Harris (2004), 3-and 4-year-olds observed two informants labeling familiar objects, where one informant was consistently reliable (e.g., labeling a ball *ball*) and the other consistently unreliable (e.g., labeling a ball *shoe*). Children were asked to identify the informant who had said something right and the one who had said something wrong. They then observed the two informants labeling a novel object using different novel words (e.g., *toma* and *mido*), and children were asked to label the novel object with the correct word. Results showed that both 3- and 4-year-olds preferred the novel label provided by the informant they had previously identified as accurate. Jaswal and Neely (2006) further showed that speakers' reliability was a more important factor than age for 3–4-year-olds when accepting new words for novel objects, with children preferring a novel label from an accurate child informant over an inaccurate adult informant. In another study, Koenig and Woodward (2010) demonstrated that even word learners as young as 2 years of age are sensitive to the prior accuracy of speakers' labeling, and that their word learning is more robust when novel words are provided by accurate speakers than by inaccurate ones. Taken together, this literature offers compelling evidence that children rely on speakers' intentions in learning the meaning of new words.

## *A pragmatic explanation of the mutual exclusivity phenomenon?*

Perhaps the most discussed phenomenon in the developmental literature on word learning is so-called mutual exclusivity, which refers to children's tendency to reject novel labels for familiar objects for which they already have names. In Markman and Wachtel's (1988) seminal study, 3-year-olds were presented with a simple disambiguation task involving two possible referents, one novel, which they did not have a word for, and one familiar, whose corresponding word they knew. When asked to pick out the correct referent for a novel label ("Show me the x"), children assumed that it referred to the novel object. This "disambiguation effect" has shown to be very robust, and one influential explanation is that children are guided by a dedicated "mutual exclusivity constraint" in word learning, which leads them to treat category labels as being mutually exclusive (Markman, 1989; Markman & Wachtel, 1988; Markman, Wasow, & Hansen, 2003; Merriman & Bowman, 1989). However, there is growing evidence for an alternative, pragmatic explanation of the disambiguation effect (see Grassmann, 2014, for a review). One is that it rests on children's expectation that conventional labels refer to familiar objects, and that a difference in lexical form marks a difference in meaning (P. Bloom, 2000; E.V. Clark, 1993; Grassmann, 2013). On this view, children's exclusion of familiar objects as referents of novel words results from inferences about speakers' word choices, rather than from any dedicated bias or constraint involved in word learning. Also, children's responses in disambiguation tasks are affected by considerations of speakers' knowledge states, with children being more likely to select the novel object as the referent of the novel word with a reliable speaker than with an unreliable one (Diesendruck, Carmel, & Markson, 2010; Sobel, Sedivy, Buchanan, & Hennessy, 2012). This suggests that children's mapping of novel labels to novel objects is guided by inferences about the speaker's intentions – if her intention was to refer to the familiar object she

would have used the conventional label – but that this assumption is suspended when interacting with an unreliable speaker. Further, as E.V. Clark (1997) has convincingly agued, there are a number of contexts in which children spontaneously use more than one label for the same object (e.g., pretense renaming: *telephone* for "banana", lexical innovation: *fire-dog* for "stray dog found at the site of a fire", taxonomies: *animal* for "cat"), and in talking to children adults may use multiple labels to pick out a single referent in combination with information about how the labels are related to one another (Callanan, 2000; Callanan & Sabbagh, 2004). This suggests that the disambiguation effect may be linked to context-specific expectations about speakers' intentions in their word choices, and that other contexts, such as pretense, may give rise to different expectations.

However, although there is much evidence in favor of a pragmatic explanation of the disambiguation effect in word learning, the debate is far from settled. Against the pragmatic account, it has been argued that children with social-pragmatic impairments also exclude familiar objects as referents for novel words (de Marchena, Eigsti, Worek, Ono, & Snedeker, 2011; Preissler & Carey, 2005). Recently, de Marchena et al. (2011) compared mutual exclusivity for words and facts in a task with children and adolescents with ASD. In the label condition, participants were shown a pair of novel objects and given a label for one of the objects ("Here's the *jop*."). Then they were asked for the other object using a novel label ("Can you give me the *wug*?"). In the fact condition, novel labels were replaced by facts about the objects ("Look at this one, *my sister gave this to me*." "Can you give me *the one my dog likes to play with*?"). Results showed that labels were treated as mutually exclusive more reliably than facts. The authors interpreted the ability of individuals with ASD to compute mutual exclusivity inferences for words as suggesting that these inferences do not rely on pragmatic reasoning, and that distinct cognitive mechanisms underlie mutual exclusivity for words and for facts (a lexical constraint and social-pragmatic reasoning respectively). While there are ways in which a pragmatic account could explain this pattern of results, taking into account the growing evidence that ASD is not characterized by global pragmatic impairments, and that the intention-reading abilities of at least a subgroup of individuals with ASD have been underestimated (Luyster & Lord, 2009), combined with considerations of whether a mutual exclusivity inference would be equally relevant in the word and the fact conditions, these results nevertheless present a challenge that pragmatic accounts of mutual exclusivity need to address.

## *Referential communication*

Referential communication is a joint activity which relies heavily on interlocutors' pragmatic competence (H. H. Clark & Bangerter, 2004). In order to appropriately use referential expressions, the speaker must be able to take the hearer's perspective in assessing his knowledge states, and appropriate reference resolution depends on the hearer's ability to track the speaker's intentions. Thus, the developmental trajectory of reference provides important insights into children's overall pragmatic development.

Children show impressive referential abilities from early on in development. In a study of 14- and 18-month-olds, Moll and Tomasello (2007) demonstrated that at both ages, infants were able to keep track of objects that they had jointly experienced with an adult, and to correctly identify another object, which only they had interacted with, as the one that the adult was excited about ("Oh, look! Look there! Look at that there! Give it to me!"). In another study, Liebal, Behne, Carpenter, and Tomasello (2009) found that at the same age, infants interpreted an adult's ambiguous pointing gesture on the basis of a recent shared experience with the pointing adult. This shows that already in the second year of life, infants are able to take some aspects of the speaker's perspective into account in assigning reference.

By age 2, children are quite good at tracking speakers' intentions, including taking into account what they know, or attend to, on a particular occasion in both comprehension and production. For instance, Moll and Tomasello (2006) demonstrated that 2-year-olds are able to understand that when an adult was asking for help in searching for a specific object, he was searching for an object that only the child could see and not one that was visible to both of them. Further, a study by Song and Fisher (2007) showed that children as young as 2;5 years are sensitive to the discourse context in interpreting ambiguous anaphoric pronouns, being more likely to select the most prominent referent (the one that was mentioned first and most often, and appeared in subject position in a narrative) as the one the speaker had intended. In a production study, O'Neill (1996) found that 2-year-olds take adults' knowledge of the location of a toy into account when asking for help in retrieving the toy, producing more toy names, location names and gestures in the direction of the toy when the adult did not know the toy's location than when it was known to the adult.

By age 3, children are able to use pronouns for discourse-given referents. In one study, Matthews, Lieven, Theakston, and Tomasello (2006) found that 3–4-year-old children chose different referring expressions (noun vs. pronoun) depending on whether the intended referent was visible to their hearer, or whether the referent had already been mentioned in the discourse. Also, Graf, Theakston, Lieven, and Tomasello (2015) found that 3-year-olds are more likely to omit arguments in a transitive construction when they are used non-contrastively than contrastively (e.g., *smells the sock* or *smells* in a context where only the fox smells the sock vs. *the fox smells the sock* when both the giraffe and the fox smell the sock). These studies show that at this age children have some mastery of the distinction between given and new information, including information that contrasts with that given in the discourse, and are able to modulate their use of referring expressions in line with the common ground they share with their interlocutors (see also Matthews, Butcher, Lieven, & Tomasello, 2012; Matthews, Lieven, & Tomasello, 2007).

Studies using referential communication tasks with preschoolers have further shown that children are sensitive to their interlocutors' perspective, and can distinguish between shared and privileged knowledge in determining the appropriate referents of complex noun phrases, although they have a way to go to reach adult levels of performance (Bahtiyar & Küntay, 2009; Nadig & Sedivy, 2002; Nilsen & Graham, 2009; Nilsen, Graham, Smith, & Chambers, 2008). For instance, Nadig and Sedivy (2002) conducted an experiment where children sat opposite an adult with a grid between them containing four items, one of which was always blocked from the adult's view. Children's production of adjectival modifiers to distinguish between referents was measured: In one condition, the target object and a contrastive object were of the same type (e.g., a tall glass and a short glass) and were visible to both participants, so the use of an adjective was required to disambiguate between the two. The second condition was the same except that the contrasting object was obscured from the adult, and so the use of an adjective would be redundant. Results showed that 5- and 6-year-old children produce more adjectival modifications (e.g., "Pick up the *tall* glass") when this is required for the addressee to disambiguate between two possible referents, than when it is required only from their privileged perspective. In a comprehension task using the same set-up, children carried out instructions such as "Pick up the glass" while their eye movements were being recorded. Nadig and Sedivy (2002) found that children were faster at identifying the target object when the contrastive object was only visible to them, than when the target and contrastive objects were visible to both participants, suggesting that children were sensitive to the speaker's perspective in assigning reference. In a set-up where children observed two adults communicate regarding the location of a hidden sticker (Nilsen et al., 2008), children's eye movements and pointing behavior showed that already 4-year-olds were sensitive to ambiguity from another addressee's perspective ("It's under

the *small cup*", when there were two cups on display), even when they themselves had privileged disambiguating knowledge. In another study, Morisseau, Davies, and Matthews (2013) used measures of reaction time and eye movements and found that both 3- and 5-year-olds responded more slowly, and were more likely to check their interlocutor's gaze, with under-informative instructions such as "Find the orange" when there was more than one orange on display than when the utterance referred unambiguously to only one orange. However, when given over-informative instructions (e.g., "Find the cat with a tail", when there was only one, normal-looking cat on display), only 5-year-olds, but not 3-year-olds, were significantly delayed and more likely to check their interlocutor's gaze. This suggests that only 5-year-olds made a contrastive inference in this condition, while 3-year-olds – who, the authors speculate, might lack sufficient cognitive resources to rapidly process the complex expression – were guided directly to the referent by the head noun before they processed the redundant information (if they did so at all). However, the type of referential communication task used may influence children's performance: Davies and Katsos (2010) found that when using a binary judgment task, where children were asked to say if a character asked for an object in a good or a bad way, children aged 5 years did not reject over-informative utterances but did so if they were allowed to give intermediary responses (by giving the character as many strawberries as he deserved for the way he asked for the object). This was interpreted as suggesting that children are more tolerant of pragmatic violations than adults are (cf. also Katsos & Bishop, 2011).

To sum up, children demonstrate impressive abilities for referential communication from the earliest stages of language acquisition. There is solid evidence that they are guided by social-pragmatic reasoning in word learning, that they readily draw inferences about the referential intentions of speakers from their uses of linguistic expressions in context and can modulate their own utterances in line with their hearers' perspectives. However, children are not completely adult-like in this domain; for instance, they may differ from adults in their sensitivity to pragmatic violations. This is one factor that has also been suggested to play a role in children's apparent difficulties with non-literal language, a topic we turn to next.

## Non-literal language use

As pragmatically able as young children clearly are, a large body of evidence suggests at the same time that until quite late in development, they seem to have difficulties with pragmatic inferences that require them to go beyond the literal meaning of the linguistic form used to obtain the meaning intended by the speaker, as in implicature and uses of figurative language. This makes pragmatic development seem like something of a puzzle: How can children be early experts at several complex pragmatic tasks but have difficulty inferring what a speaker means in using an expression with a non-literal meaning?

### *Scalar implicature*

A particularly active research area within developmental and experimental pragmatics addresses children's and adults' understanding of so-called *scalar implicatures*. These involve speakers using a weak member of a scale (e.g., *some*) to imply that the stronger member of the scale (e.g., *all*) does not hold. An example is the utterance *Some politicians are honest*, implying "Not all politicians are honest". One reason why scalar implicatures have attracted such interest from researchers in theoretical and experimental pragmatics is their potential to inform pragmatic theories regarding the nature of implicatures and the semantic-pragmatics divide. According to Neo-Gricean approaches (e.g., Horn, 1972; Levinson, 2000), scalar implicatures are automatically computed

when hearers encounter a scalar term in an utterance. They are based on the existence of a logical and context-independent informativeness scale of propositions containing the scalar expression used (e.g., *some*) and its alternatives (e.g., *all*), where the most informative proposition entails the less informative one(s). Assuming that speakers adhere to Grice's first maxim of Quantity (Grice, 1975/1989), according to which they should be as informative as required in the particular context, the existence of a more informative proposition that would have been relevant in the context, but that the speaker has chosen not to utter, suggests that the more informative proposition is false. In contrast, the relevance-theoretic approach (e.g., Carston, 1998; Noveck & Sperber, 2007; Sperber & Wilson, 1986/1995) treats scalar implicatures as regular pragmatic inferences that the hearer draws in the overall process of arriving at an interpretation that meets his expectation of relevance (where "relevance" is defined as a trade-off between cognitive effects and processing effort). Rather than being automatically triggered by the occurrence of a scalar term, the derivation of scalar implicatures typically requires an extra processing cost which is offset by extra cognitive effects, such as a more informative interpretation.

While adults have been shown to be very good at drawing scalar implicatures (e.g., Breheny, Katsos, & Williams, 2006; Y. T. Huang & Snedeker, 2009a), a number of developmental studies have found that before the age of 5 years, children have difficulties deriving such inferences (e.g., Barner, Brooks, & Bale, 2011; Guasti et al., 2005; Y. T. Huang & Snedeker, 2009b; Noveck, 2001; Papafragou & Musolino, 2003). In these studies, which typically use truth-value or acceptability judgment tasks to assess children's comprehension, children are presented with an utterance containing a scalar term (e.g., "Some of the cats are brown") and a situation in which the utterance would be logically true if the scalar implicature is not drawn (e.g., where all the cats are in fact brown), and are asked to judge whether the utterance is true or false, or whether a puppet "said it well or not", about the situation in question. Most studies find that children tend to treat such utterances as true or acceptable, suggesting that they do not draw scalar implicatures, in contrast to what adults typically do (e.g., Papafragou & Musolino, 2003).

Given the broader developmental literature on children's pragmatic abilities, as previously outlined, showing not only that children rely on pragmatic reasoning in pre-linguistic communication and word learning, but also that they have an early sensitivity to informativeness, as evidenced by their early ability to modulate their use of referring expressions depending on their interlocutor's perspective and knowledge state, several authors have considered whether other factors than a lack of pragmatic maturity might account for children's apparent difficulties with drawing scalar implicatures. Based on the theoretical positions outlined above, different explanations of children's difficulties in this domain have been proposed (see Katsos, 2014, for a discussion).

*Lexicalist accounts* (e.g., Barner et al., 2011; Chierchia, Crain, Guasti, Gualmini, & Meroni, 2001; Guasti et al., 2005; Hochstein, Bale, Fox, & Barner, 2014; Stiller, Goodman, & Frank, 2015; Tieu, Romoli, Zhou, & Crain, 2016) propose that although children have the necessary pragmatic competence to compute implicatures, they may lack knowledge of or access to relevant scalar alternatives to expressions such as *some*. For instance, in one experiment, Barner et al. (2011) asked children questions about a group of three animals (a dog, a cat and a cow), in which a property was true of some or all members of the group. In the critical condition where all three animals were sleeping, children responded affirmatively when asked whether "some of the animals are sleeping", consistent with previous work on the development of scalar implicature, but also when asked whether "only some of the animals are sleeping". However, when children were simply asked whether "only the cat and the dog are sleeping", the large majority of them correctly rejected the statement, suggesting that their acceptance of the "only some" question was not due to a lack of understanding of the meaning of *only*, and that when members of the

scale were explicitly provided, their scalar implicature derivation improved significantly. Barner and colleagues took their results to suggest that children were unable to access *all* as the scalar alternative to *some*, even when this was predicted to be grammatically required (*only* presumably requires accessing and negating appropriate alternatives). So even if they understood that *some* was not maximally informative in the given context, they were not able to access the relevant alternative *all* in order to compute the scalar implicature.

*Context-driven processing accounts* (e.g., Pouscoulous, Noveck, Politzer, & Bastide, 2007) propose that, given that scalar implicatures are costly to derive, children may lack the full resources necessary to execute one or more of the steps of the scalar inference. On this account, inspired by relevance theory (Carston, 1998; Noveck & Sperber, 2007; Sperber & Wilson, 1986/1995), scalar implicatures do not involve accessing lexical scales but are ordinary pragmatic inferences drawn by hearers in order to arrive at an interpretation that satisfies their expectations of relevance. For instance, in a set of experiments, Pouscoulous et al. (2007) investigated whether reducing the cognitive resources required to draw a scalar implicature would reveal an earlier competence. In an act-out task, children aged 4–7 years were presented with five boxes, each of which contained a token, and a critical condition where a puppet said, "I would like some of the boxes to contain a token". Results showed that the majority of their 4-year-olds were able to draw scalar inferences (i.e., they removed some of the tokens from the boxes), and that performance improved with age. The authors interpreted this as suggesting that complexity – translated into processing effort – is an important factor in children's understanding of scalar terms.

Thus, the task that children are asked to perform does seem to influence their ability to derive implicatures, and the use of more child-friendly and ecologically valid tasks may reveal an earlier competence (Papafragou, Friedberg, & Cohen, 2017; Papafragou & Tantalou, 2004; Pouscoulous et al., 2007). In the standard truth-value judgment task used to test understanding of scalar implicature, children have to judge the truth or falsity of a statement produced out of context, which does not correspond to the normal situations in which hearers derive implicatures. Furthermore, Katsos and colleagues (e.g., Katsos & Bishop, 2011) have argued that this task cannot distinguish an inability to draw scalar implicatures from a general tolerance of pragmatic violations (i.e., children may be less sensitive than adults to the infelicity of *some* in an *all* context, without being unable to draw the implicature), and may therefore misrepresent children's actual competence.

A factor that has recently received some attention in the developmental literature on scalar implicature understanding is children's ability to consider the relevance of the alternatives. Skordos and Papafragou (2016) designed a set of experiments to investigate whether the main factor responsible for children's difficulty with these inferences is the accessibility of scalar alternatives (cf. the *lexicalist account*) or the product of a mechanism that also assesses conversational relevance (cf. the *context-driven processing account*). They tested 5-year-olds on a standard acceptability judgment task, in which children were presented with pictures of characters and objects and accompanying statements ("*All/some* of the blickets have an umbrella") that were either felicitous or infelicitous. Their first experiment manipulated the order of presentation of the *all* and *some* sentences, and in the critical condition, the stronger lexical scale member *all* had always been made highly accessible during children's evaluation of *some* statements. Results showed significantly more correct responses to *some* statements when the stronger lexical member *all* had been explicitly mentioned, consistent with the lexicalist account. The second experiment used a similar set-up and was designed to manipulate the conversational relevance of the scalar alternatives. Children were first presented with a block of *all* statements, and assigned to two conditions: In one condition, they were asked to evaluate the statements on the basis of quantity ("Do *all* or *only some* of the blickets have an umbrella?"), and in another condition, on the basis of the

objects involved ("Do the blickets have *an umbrella* or *another object*?"), before being presented with *some* statements. Results showed that children provided more correct (pragmatic) evaluations in the Quantity condition than in the Object condition, suggesting that the conversational relevance of the alternatives plays a role in children's understanding of scalar implicatures. This also provides evidence against the lexicalist account, which does not predict a difference in performance between these two conditions, given that the stronger member of the scale (*all*) is provided for children in both cases. The third experiment in Skordos and Papafragou's (2016) study focused on the Quantity condition and presented children with either a block of *all* statements or *none* statements. While *none* is not a member of the <*some* . . . *all*> scale, it is also a quantifier and might help children reason about relevant alternatives and enable them to draw the scalar inference with *all*. However, if children have difficulties spontaneously accessing the stronger member of the lexical scale, as maintained by the lexicalist account, implicature generation should be facilitated with *all* statements but not with *none* statements. Results showed no difference in performance between these two conditions, with children deriving scalar implicatures in both. This shows that even when *all* was not explicitly present, children were helped by cues establishing the conversational relevance of the alternatives to spontaneously access *all* in deriving the scalar implicature.

The scalar implicature phenomenon has generated a large number of studies and continues to be a center of interest in experimental and theoretical pragmatics, due to its potential to inform pragmatic theories of utterance understanding and as a test case for children's pragmatic competence. As a result, an increasingly nuanced and complex picture of children's abilities in this area is emerging. However, there is currently little interaction between this literature and that on figurative language acquisition, which is another area of non-literal language use where children have been shown to experience difficulties, although the results are mixed.

## *Figurative language*

Figurative use of language, the pragmatic phenomenon par excellence, involves utterances where the speaker-intended meaning goes far beyond what is semantically encoded by the words used, and where there is often a complex interplay between contextual factors, conceptual and world knowledge and relevance considerations. An important question in developmental pragmatics is therefore how children cope with figurative uses, such as metaphor, metonymy and irony.

By far most research on figurative language development has focused on children's ability to produce and understand metaphor (e.g., *John is a lion*, conveying that John is very strong) (for reviews, see Gibbs, 1994; Pouscoulous, 2014; Vosniadou, 1987; Winner, 1988/1997). The earliest studies of metaphor acquisition focused on spontaneous metaphors in the speech of preschool children (Billow, 1981; Gardner, Winner, Bechhofer, & Wolf, 1978; Winner, McCarthy, & Gardner, 1980; Winner, McCarthy, Kleinman, & Gardner, 1979). One example: An 18-month-old boy calls a toy car a *snake* while twisting it up his mother's arm. However, a matter of contention in this literature is whether such uses qualify as "real metaphors", comparable to those produced by adults, or if they are more appropriately analyzed as over-extensions, i.e., erroneous extension of a known term's conventional denotation on the basis of perceptual similarity (e.g., *ball* referring to the moon), and renamings, where the child already knows the term for an object but chooses to call it something else in the context of pretend play (e.g., calling a banana a *telephone*, while holding it up to the ear).

Based on evidence from children's abilities with metaphor, we can broadly distinguish two hypotheses about the course of figurative language acquisition, *the literal stage hypothesis* and *the*

*early onset hypothesis*. *The literal stage hypothesis* arises from the observation that the occurrence of spontaneous "metaphors" in the speech of preschool children tends to decrease with age (Billow, 1981; Gardner, Kircher, Winner, & Perkins, 1975) and that children of elementary school age tend to have difficulties understanding metaphors (Asch & Nerlove, 1960; Billow, 1975; Winner, Rosenstiel, & Gardner, 1976). To explain this, several researchers have proposed that there is a literal stage in figurative language development (Asch & Nerlove, 1960; Levorato & Cacciari, 2002; Winner, 1988/1997; Winner et al., 1976): After an early phase of creative linguistic behavior, children enter a literal stage during the elementary school years characterized by a decrease in their production of figurative language and a tendency towards literal interpretations, before a more sophisticated level of figurative language skill is attained in early adolescence. For instance, Levorato and Caccari (2002, p. 129) have claimed that up to about age 7, a primitive type of processing is prevalent which involves "a piece-by-piece elaboration of the linguistic input; children process language literally even when it does not make sense in the linguistic context".

Proponents of *the early onset hypothesis* have criticized the idea of a literal stage in figurative language development, mainly because of the growing evidence that attests to the presence of an early metaphorical competence, possibly emerging as early as the preschool years (Deamer, 2013; Gardner, 1974; Gentner, 1977; Gibbs, 1994; Gottfried, 1997; Keil, 1986; Pearson, 1990; Pouscoulous, 2011; Stites & Özçaliskan, 2013; Vosniadou, 1987; Vosniadou, Orthony, Reynolds, & Wilson, 1984; Özçalışkan, 2005). It has been suggested that the lack of understanding found by the early studies of children's metaphorical abilities could stem in part from the complexity of the tasks used, which often required the children to paraphrase or explain the metaphorical meaning. Preschool children perform better on forced-choice tasks, where they are asked to choose the correct metaphorical meaning from a set of alternatives (Waggoner & Palermo, 1989; Winner, Engel, & Gardner, 1980; Özçalışkan, 2005), to retell a story containing a metaphor (Pearson, 1990) or to act out the metaphorical meaning (Vosniadou & Orthony, 1986). In short, their difficulty may stem from the tasks used to tap the metalinguistic abilities required for putting metaphorical meanings into words.

Second, early studies of metaphor comprehension did not take sufficient account of children's limited world knowledge, and also presented the metaphorical sentences in isolation, without supporting contexts. But children's metaphor comprehension depends critically on their conceptual knowledge about the domains that a metaphor instantiates (Keil, 1986), and contextual information helps children decide whether an expression should be interpreted metaphorically or not (Vosniadou, 1989; Vosniadou et al., 1984). Taken together, the present evidence suggests that the same children might be able to understand a metaphor if presented with a forced-choice task, where the context is made predictable and the metaphorical domains correspond to the child's world knowledge, but not otherwise. But if metaphorical competence developed in stages, this would mean that the child could be in the literal and non-literal stages at the same time. Thus, the early onset hypothesis about the course of figurative language development makes no claim about a literal stage but assumes, based on recent evidence, a figurative language ability that emerges during the preschool years, developing steadily throughout childhood (Gottfried, 1997; Stites & Özçaliskan, 2013; Vosniadou et al., 1984; Özçalışkan, 2005). The ability to understand and produce metaphors precedes the ability to verbally explain metaphorical meanings (Keil, 1986; Stites & Özçaliskan, 2013; Özçalışkan, 2005).

Less than a handful of studies have investigated children's production and comprehension of metonymy (e.g., *The ham sandwich left without paying*, where *The ham sandwich* refers to the customer), but they all attest to an early-emerging ability (Falkum, Recasens, & Clark, 2017; Köder & Falkum, 2016; Nerlich, Clarke, & Todd, 1999; Rundblad & Annaz, 2010b; Van

Herwegen, Dimitriouc, & Rundblad, 2013). Falkum, Recasens, and Clark (2017) investigated metonymy production and comprehension in children aged 3 to 5 years. In two semi-structured elicitation tasks, they found that metonyms were prevalent in the productions of all age groups. To test metonymy comprehension, children were presented with a forced-choice story task using pictures. Children were first shown a context picture and told a short story about the two characters in the picture, one of whom had a salient property (a large nose, bicycle helmet, etc.). Then the target sentence had the salient property of this character as its subject, and was used to make either a metonymic or a literal reference (e.g., "*The helmet* rides home"). Children were asked to select the matching picture from a set of three smaller pictures, close-ups of each individual in the story (the metonymic referent and the other character) and the salient property by itself (the literal referent), and to explain their choice. Results suggested that by age 3, children are able to understand some novel metonymic uses in context, although they have a way to go before they reach an adult level of understanding. Children also became better at explaining their choices of target metonymic interpretations with age. Surprisingly, however, performance on the picture selection task decreased with age, with 5-year-old children being more likely to interpret metonyms literally. A possible explanation of this finding might be that children's figurative language ability may, at a certain stage, be affected by the development of other communication-relevant abilities (cf. Gibbs, 1994; Pouscoulous, 2014). For instance, a growing metalinguistic ability – as suggested by their better performance in the verbal explanation part of the task – may have pushed the older children to over-emphasize the literal meanings of target sentences. Results from a follow-up study combining picture selection and eye tracking (Köder & Falkum, 2016) reveal a similar pattern on both measures in children from a wider age range, with 4–5-year-old children being more likely than 3-year-olds, 6-8-year-olds and adults to choose the picture that depicts the literal interpretation of a target metonymic expression (e.g., choosing a picture of a guitar instead of the man playing the guitar for "*The guitar* is hungry"). The gaze data, however, show that all age groups look significantly more often at the correct metonymic target than at the literal competitor during the processing of the metonymic target utterances, suggesting a clear sensitivity to metonymic uses, even among those children who choose literal interpretations in the offline picture selection task. Interestingly, in the group of children aged 4–8 years, results also revealed a time window after hearing the metonymic target where children look equally often at the target and the literal competitor before they return to the metonymic target again. The results also indicate that offline measures such as picture selection tasks, which are standard in the developmental field, could potentially underestimate children's competence. We should therefore be cautious about concluding from children's "literal preference" in such tasks to a lack of figurative language understanding and pragmatic immaturity. This suggests that children in this age range experience a stronger competition from the literal interpretation than 3-year-olds and adults do. Further studies using this methodology which combines online and offline measures may allow us to get deeper insights into the cognitive underpinnings of children's "literal preference" during this stage of pragmatic development.

As concerns irony (e.g., *What lovely weather today*, uttered in a downpour), there has been a growing interest in its development in recent years, although empirical investigations have been far fewer than for metaphor. Most research suggests that irony understanding is a relatively late acquisition, emerging around age 6, and that before this age children tend to interpret ironic utterances as ordinary "literal" utterances (Creusere, 1999; Filippova & Astington, 2010; Glenwright & Pexman, 2010; Hancock, Dunham, & Purdy, 2000; Winner, 1988/1997). An explanation of the late acquisition is the complexity of irony, and that, unlike metaphor and metonymy, its comprehension requires the hearer to recognize that the speaker is distancing herself from the literal content of the utterance she has produced; that is, it requires second-order metarepresentational abilities (e.g., Happé, 1993). However, links between theories of irony processing

and developmental studies have been largely absent (Creusere, 1999; Keenan & Quigley, 1999; Wilson, 2013; but see Keenan & Quigley, 1999). As a consequence, a wide variety of operational definitions are used in the developmental literature, where irony is often understood in a very broad sense to include, for instance, hyperbole, understatement, satire/parody and rhetorical questions (see, e.g., Reccia, Howe, Ross, & Alexander, 2010). But is not clear that these phenomena all involve the same pragmatic mechanism, and, consequently, whether they should all be expected to follow the same developmental trajectory. Further, task complexity is also an issue in studies of irony comprehension, where participants are typically asked rather complex comprehension questions such as "Did X really mean that *p*?" or "Why did X say that *p*?" requiring quite developed verbal reasoning abilities. A promising direction in research on children's irony comprehension is the use of online measures such as eye tracking, which, through the use of more child-friendly tasks and implicit comprehension measures, may give us a better picture of children's actual competence with irony (Climie & Pexman, 2008; Falkum & Köder, 2018).

In the developmental pragmatics literature, children's abilities with non-literal uses of language have been taken as a good test case for their pragmatic abilities more generally. However, given the range of factors that seem to play a role for children's success (or lack thereof) in these tasks, this assumption could be questioned. While recent studies in the field of scalar implicature which take relevance considerations into account may have taken us one step closer to an account of children's abilities in this area, the factors underlying preschool children's apparent "literal preference" in figurative language comprehension remain not well understood, and this is a pressing issue that future research needs to address.

## Individual differences in pragmatic development

While a growing body of research is providing us with an increasingly complex and nuanced picture of the pragmatic abilities of typically developing children, it also reveals substantial individual differences in pragmatic development (see Matthews, Biney, & Abbot-Smith, 2018, for a review). As already mentioned, one group that has received particular focus in this research context is children with ASD, whose pragmatic impairments have been considered a hallmark of the disorder (Tager-Flusberg, Paul, & Lord, 2005) and are hypothesized to be linked to different sources (Norbury, 2014a): First, the socio-cognitive deficits associated with the diagnosis, more specifically a fundamental impairment in "theory of mind" abilities (Baron-Cohen, Leslie, & Frith, 1985) and resulting difficulties understanding the speaker's intention, could underlie the limitations this group demonstrates in referential communication (Malkin, Abbot-Smith, & Williams, 2018; Nadig, Vivanti, & Ozonoff, 2009; Norbury & Bishop, 2003) and comprehension of uses of figurative language (Happé, 1993; Rundblad & Annaz, 2010a). Second, weak central coherence (WCC), that is, a cognitive style that biases local over global, holistic information processing in individuals with ASD, could make the integration of information in context difficult, with consequences for all areas of pragmatics (Happé, 1999). Third, deficits in executive function in the ASD population, that is, the set of cognitive abilities involved in goal-directed behavior, including, *inter alia*, inhibitory control and mental flexibility (Hill, 2004), could underlie difficulties in figurative language comprehension, which requires inhibition of the literal meaning and flexibility in going beyond rigid, literal interpretations.

Recently, however, a growing number of studies have suggested that the widely variable population of ASD individuals may not be characterized by global pragmatic impairments (e.g., Hochstein, Bale, & Barner, 2018), and that some of the recognized pragmatic deficits may be associated with impaired language abilities rather than with autism-specific limitations

in social cognition (Norbury, 2005; for a recent account of the relation between pragmatic abilities and language skills in atypical development, see Chapter 17, this volume). Furthermore, children can have significant pragmatic impairments (as reflected by the diagnosis social (pragmatic) communication disorder, recently added to the DSM-V framework) without meeting diagnostic criteria for autism (for discussion, see Norbury, 2014b). Future research should seek to provide more nuanced, theoretically informed accounts of communicative patterns within subgroups of the ASD population, and in the wider domain of atypical pragmatic development.

## Summary

Children are born communicators. From the first months of life, infants are able to detect ostensive communication directed at them in the form of eye contact, motherese and temporal contingency. Around 9 months they start engaging in acts of joint attention with their caregivers, providing the foundation for the emergence of pre-linguistic gestures between 9 and 12 months of age and language in the second year of life. Children rely on their pragmatic abilities in word learning, which requires intention reading, some forms of perspective taking and inferences about speakers' choice of gestures and words. By age 2, children are quite good at tracking speakers' intentions, including taking into account what they know, or attend to, in using and understanding referring expressions, and by age 3, children are able to use pronouns for referents that are given in the discourse. Studies using referential communication tasks with preschoolers have further shown that children are sensitive to their interlocutors' perspective, and can distinguish between shared and privileged knowledge in determining the appropriate referent of complex noun phrases. This still growing evidence has shifted the general view of children's early pragmatic abilities from an assumption of pragmatic insensitivity to one of pragmatic sophistication. However, children's success in tasks involving pragmatic interpretation is to some extent fragile. In particular, they seem to have some difficulty coping with non-literal uses of language in the form of implicatures and figurative language. While part of this difficulty could be attributed to the cognitive demands of the tasks used to test children's comprehension rather than to lack of pragmatic maturity, there is clearly something about such uses which poses a challenge to children's acquisition. Some factors that have been suggested to play a role are children's processing limitations, relevance considerations, pragmatic tolerance and developing metalinguistic awareness. The developmental literature on ASD and social (pragmatic) communication disorder reveals substantial individual differences in pragmatic development, the underlying causes of which are currently debated. Further research is needed in order for us to build a clearer overall picture of children's developing pragmatic abilities, from both typical and atypical perspectives.

## Notes

1 Following Grice, most pragmatic theories focus on the interpretation side of communication. In the developmental pragmatics literature, however, production studies provide important insights into children's pragmatic abilities, which is also reflected in the present chapter.
2 See Sperber (1994) for a discussion of an utterance of *It's late* in other contexts.
3 This does not mean that language has no role in pre-verbal communication. Even 6-month-olds have been shown to have a rudimentary word comprehension, even in non-communicative contexts (e.g., Friedrich & Friederici, 2011).

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# 14

# THE ROLE OF INPUT IN SYNTAX AND MORPHOLOGY ACQUISITION

## Evidence from production

*Amanda Owen Van Horne*

The use of grammar is often presented as *the* component of language that is uniquely human, which takes language beyond a basic instinctual communication system and into the realm of an infinitely combinatorial symbol system that can communicate abstract ideas efficiently. In general, when grammar is presented in this way, the focus is on how it came to be that language is learnable and accessible to nearly all people – or at least to all people with typical cognitive and social skills who are exposed to an adequate amount of language in a reasonably communicative context (Hoff, 2006). In doing so, the research programs illuminate what makes us uniquely human or what makes humans uniquely capable of learning language, the focus becomes ethological in nature, and the emphasis is largely on the presence or absence of language.

However, it is also the case that there exists a wide range of individual differences in the acquisition of language (Kidd, Donnelly, & Christiansen, 2017). Most of the time variation is captured via tests of vocabulary knowledge, but individual differences also exist in the area of grammatical development (Huttenlocher, Vasilyeva, Cymerman, & Levine, 2002). Some children combine words early and quickly, while others do so much later. Some children make many over-regularization errors, while others systematically inflect words correctly. Some children produce sentences with words in the wrong order, while others rarely do so. In general, when grammar is presented in this way, the focus of the research program is on what aspects of the environment and what child characteristics influence the rate and degree of learning (Hoff, personal communication). In doing so, these research programs illuminate the cognitive mechanisms that support language learning and allow the identification of strategies that may improve language outcomes. In this chapter, we approach the question from this second perspective.

### Early combinatorial skills

The first observable use of grammar in children occurs with the onset of two-word phrases. This milestone is tightly related to vocabulary size, with two-word combinations first observed around 18 months, when a child has accumulated an expressive vocabulary of 50–100 words. In fact, expressive vocabulary size appears to be a more reliable predictor of grammatical skills than age, a finding that holds cross-linguistically (Bates & Goodman, 1997; Conboy & Thal, 2006;

Mariscal & Gallego, 2012). This relationship appears to be strong in most typical children and somewhat less robust at the extremes, both for children with very small vocabularies for their age (Moyle, Ellis Weismer, Evans, & Lindstrom, 2007) and for precocious children (Thal, Bates, Goodman, & Jahn-Samilo, 1997).

Much work in the 1980s and 1990s made the case that the accumulation of sufficient linguistic exemplars for the onset of combinatorial language is necessary, known as the Critical Mass Hypothesis. This hypothesis extends the influence of vocabulary size on grammar to other areas, including morphology, and is well supported by computational models and cross-linguistic data. However, more recent work has shown that evidence of combinatorial skills is present earlier than the onset of the two-word stage and that these earlier combinatorial skills also predict later grammar use. For instance, gesture + gesture and gesture + word combinations predict the onset of two-word combinations and continue to predict grammatical proficiency into later stages (Özçalışkan & Goldin-Meadow, 2005). See Table 14.1 for examples of gesture combinations. Critically, it is the number of different combinations, and not the number of different meanings communicated via gesture, that supports later grammatical outcomes, indicating that gesture is not substituting for the lexicon but rather is truly related to the child's ability to combine (Rowe & Goldin-Meadow, 2008). Gesture, likewise, can serve as a good prognostic indicator, with early research showing that children who were initially identified as late talkers were more likely to catch up and be re-identified as late bloomers if they showed good use of gesture and gesture combinations. Children who failed to use gesture well were more likely to go on to be identified as children with language impairments (Thal & Bates, 1988; Thal, Tobias, & Morrison, 1991).

This begs the question – is it that children who are good at gesture and vocabulary are just generally good at language? Or is it that vocabulary size critically underpins the next stages of grammatical development? We turn to bilingual children for an answer to that question. If vocabulary size, rather than being generally good at forming grammatical combinations, is the critical factor, then we should see that the size of the vocabulary in one language drives the growth of grammar in that language only. If, on the other hand, being good at grammar and good at vocabulary indicate an underlying language-learning proficiency, then we should see

*Table 14.1* Types of gesture and their interpretations.

| *Category* | *Child communication* | *Interpretation* |
|---|---|---|
| Gesture + gesture combination | | |
| | Point + puckered lips | See bubbles |
| | Closed fist lifted by flat hand + rubbing chest | Please help |
| | Tapping hands together + an open hand at mouth | More drink |
| Gesture + word combinations | | |
| *Supplementary (gesture adds information to words)* | "Eat" + point at bread | Eat bread |
| | "Open" + point at closed gate | Open the gate |
| | Gesture for ball + "Throw at me" | Throw me the ball |
| *Complementary (gesture repeats information in words)* | "Give-it a me" + patting self | Give it to me |
| | Making an inchworm motion with hand + "Worm go" | Worm go |

highly similar rates of growth in grammar in both languages regardless of the vocabulary size in each. Early findings demonstrated that growth in vocabulary in one language predicted grammatical growth in that language and vocabulary growth in the second language, but did not predict grammatical skills in the second language (Marchman, Martinez-Sussmann, & Dale, 2004; Simon-Cereijido & Gutiérrez-Clellen, 2009). This would suggest that it is a within-language critical mass of exemplars that drives grammar acquisition in that language. Similarly, Hoff, Quinn, and Giguere (2017) found correlations within languages, but not between languages, for grammar and vocabulary in young sequential bilinguals. In contrast, in a study of sequential bilinguals who were somewhat older, Castilla, Restrepo, and Perez-Leroux (2009) found that preschool children who were strong in both vocabulary and grammar in their first language also showed gains in both in their second language. They attributed these results to underlying language-learning ability rather than to cross-linguistic transfer since the link to the second language vocabulary size was weaker and the overall effect was driven by the first language. The discrepancy may be due to the fact that this later study examined sequential, rather than simultaneous, bilinguals, or that the children were much older, just finishing preschool.

These early two-word combinations provide the earliest evidence of combinatorial skills (and therefore the earliest potential evidence of syntax), but their characterization and classification as carrying specific syntactic information has been debated. The debate has included claims about whether children ever confuse grammatical classes (for example, substituting nouns for verbs), whether children abide by word order in languages such as English, and whether they are completely creative in their combinations as opposed to building on previously heard combinations.

The number and variety of combinations expand very rapidly, suggesting that children are relying on some kind of productive, combinatorial strategy, but what that strategy is remains under discussion. Early work was divided over whether to classify two-word combinations as based on the semantic relations described or grammatical information involved. Analysis based on semantic relations emphasized that children might be organizing their utterances based on meaning alone without regard to syntactic roles. Thus, simple utterances might be characterized as action-object (*push truck*) or possessor-possession (*my hat*) (Bloom, 1971). The inherent ambiguity of understanding and interpreting very short utterances is highlighted here in a single utterance (classically, "mommy sock") that can be interpreted in many ways, including possessor-possession ("that is mommy's sock") and agent-action ("mommy put on the sock"; Bloom, 1971).

Pivot grammar, or limited scope formulae, analyses provided the foundation for much of today's work on lexically specific constructions. These emphasized a fixed high frequency word (*it*, *on*, *my*) combined with an open slot that could be filled by a variety of less common lexical items (*open it*, *gimme it*, *read it*; *hat on*, *sock on*, *light on*; *my hat*, *my book*, *my chair*). Fixed (or Pivot) words could occur at either the beginning or end of the two-word combination, but typically a particular word, like *it* in the examples above, would only occur in a single position. There was much discussion as to whether the open slot words could occur in multiple positions (as with *hat* in the above examples) or were restricted to a single position (Braine, 1976).

Frequent combinations of words may provide information to children about grammatical classes, which they can then use to connect words to grammatical categories (Mintz, 2003). For instance, Mintz found that in all six corpora that he analyzed, children heard a frame like *you* ____ *me* in which the intervening word was a verb. Other frequent frames bracketed word classes like nouns (*put* ____ *in*) or adjectives (*the* ___ *one*). Weislander and Waxman (2010) have extended this analysis approach to Spanish, a potentially challenging language because word order is less fixed than in English and noun drop is allowed in the adult grammar for both

subjects and objects, making the frames less likely to be reliable. Although the classification accuracy was somewhat lower for Spanish, it still reliably exceeded chance, providing support for this approach cross-linguistically. Nonetheless, Mintz's work on frequent frames has been challenged on the grounds that to identify a frame that is useful, a child would have to be tracking distributional information over time without knowing in advance that certain non-adjacent combinations were the ones requiring attention. The computational capacity required to carry out such tracking might rapidly exceed a child's capacity (Bannard & Lieven, 2009).

Alternatively, children may not be identifying grammatical classes until much later. Instead of using frequent frames to identify grammatical classes, children may be learning sequences of words and morphemes and then combining these sequences with a minimum level of productivity. Thus, children may initially be using holophrastic utterances (e.g., *Where daddy go?*) and then using one element in the utterance in a restricted but more flexible manner (e.g., *Where PERSON go?*), ultimately making it a fully productive utterance that allows flexible use of both the noun and the verb (e.g., *Where did the car drive?*; Theakston & Lieven, 2017). Just over half of all of the parental utterances in their sample of child-directed speech could be classified into a rather small subset of constructions beginning with the same one to three words (*what's + X*, *It's a + Y*, etc.; Cameron-Faulkner, Lieven, & Tomasello, 2003). Thus, children may not initially be relying on grammatical classes *per se*, but rather semantic regularities combined with formulaic multi-word sequences (Theakston & Lieven, 2017).

## Simple syntax

As children's utterances lengthen, they begin producing early utterances that can more readily be assigned to adult-like syntactic frames. A variety of changes, all of which lengthen and transform two-word utterances into simple sentences, occur in a fairly short period of time. These include the inclusion of sentence subjects; the use of function words and grammatical morphemes; and the addition of direct objects, indirect objects, and prepositional phrases to add information to the predicate. We have reviewed evidence that there is considerable variation in the onset of two-word combinations and will shortly review evidence of variation in complex syntax, but there appears to be much less variation in the development of simple syntax (Huttenlocher et al., 2002). It is much harder to detect individual differences in simple syntax attainment. This has led to some speculation that there is a relatively low threshold of input that must be crossed in order to acquire these simple forms and that this threshold is readily crossed by nearly all households and families. There is work, nonetheless, that shows that children are attentive to the input as they transition into the use of full grammatical frames. This includes evidence that children use words conservatively, in the syntactic frames that they have most often heard them in, and that they draw on regularities in the input in order to move from item-specific productions to more abstract uses. The best evidence examines dense corpora of child-caregiver interactions rather than aggregating over large groups of children since the patterns observed for one dyad are often different from those observed for another dyad. Studies of high density developmental corpora combined with experimental studies have provided the best evidence at this stage as to how much learning is derived from input (Rowland & Fletcher, 2006; Tomasello & Stahl, 2004).

One feature of English is that some verbs can occur in both transitive and intransitive utterances (e.g., *the bear is rolling the ball*; *the ball is rolling*), but many cannot (e.g., *the girl sneezed*; **the monkey tickled*; *the monkey tickled the girl*; **the girl sneezed the monkey*). Corpus studies of children's verb use suggests that at least initially verbs are used in a single frame (Lieven, Pine, & Baldwin, 1997) and that there is very little abstraction across frames (Brooks & Tomasello, 1999). Even different forms of the same verb (e.g., *go*, *going*, *gone*, *went*) may show up in semantically and

syntactically distinct frames in very early uses (Theakston, Lieven, Pine, & Rowland, 2002). Experiments confirm this conservative approach and suggest that this is because children use verbs in the forms that they hear them in and are reluctant to extend verbs to new frames without clear evidence that more than one frame is possible (Braine & Brooks, 1995). For instance, very young (2;0–2;6) children were exposed to new made-up verbs that expressed a causative meaning in intransitive utterances (*It's meeking*). These children were extremely reluctant to use those verbs in transitive utterances (*he's meeking it*) even when the questions used strongly encouraged the use of this frame. This effect increased with age. In a classic study, Akhtar and Tomasello (1997) demonstrated that very young children, but not older children, would use novel verbs in non-English word orders. Specifically, they taught 2-, 3-, and 4-year-old children three novel verbs associated with three transitive actions in three word orders: Subject Verb Object (SVO), Verb Subject Object (VSO), and Subject Object Verb (SOV). Only SVO is attested in English. All groups of children used the novel verb in English word order. However, only the 2-year-old group used the novel verbs in the non-English word orders consistent with the order they heard them in. The older children corrected the word order to the English SVO.

Although this approach has been termed the "verb-island account", so termed because of the intuition that children treat each verb as an island without linking it to other verbs or constructions to form an abstract pattern, the findings are not unique to verbs. Similar findings exist for the use of determiners with nouns (e.g., *a*, *the*). While it is taken for granted that adults may use *a/an* and *the* flexibly with any noun (*a* chair, *the* chair; *an* idea, *the* idea), children instead use *a/an* with a restricted subset of nouns and use *the* with a different, non-overlapping subset, reflecting more item-based combinations (Pine & Lieven, 1997; Pine, Freudenthal, Krajewski, & Gobet, 2013).

Pronouns provide clear information to English-speaking children about how argument structure works, since pronouns both are marked for case (*he*, *him*) and tend to appear in a fixed order within a sentence. Children are more likely to learn and use a novel verb when the arguments around the verb are pronouns (*he's verb-ing it*) than full nouns (*The boy's verb-ing the ball*), presumably because this makes it easier for children to align the arguments and extract the verbs' meaning (Childers & Tomasello, 2001). Children are also conservative in the noun phrases that they use as subjects with particular verbs, limiting those to what they have heard in the input. For instance, children may only use the verb *kick* with a proper name of a person as the subject. Pronouns provide flexibility in meaning that lexical nouns do not (e.g., *she kick me*; *I throw it*). Pronouns, more so than nouns, are likely to appear in both subject and object position. There is also limited flexibility in the object position, with more than 75% of early objects being produced as *it* for children under 2;6 (Theakston, Maslen, Lieven, & Tomasello, 2012). Even so, the locus of creativity in the speech of children under age 3 appears to be in the type and variety of objects that they combine with verbs (Theakston, Ibbotson, Freudenthal, Lieven, & Tomasello, 2015). Examination of the developmental trajectory of children's syntactic frames has led Hadley and colleagues to suggest that actively diversifying the number of subject + verb and verb + object combinations that children produce is one way of accelerating their language development (Hadley, 2014).

While children are sensitive to restrictions on what type of syntactic frame a verb should appear in, they do make mistakes (e.g., *She giggled me*; Bowerman, 1982), and researchers have asked how children come to use a syntactic frame with a semantic verb class and how they come to correct themselves when they have overgeneralized a verb as being used in the wrong syntactic frame. The FIT hypothesis (Ambridge & Lieven, 2011) captures several factors that have been shown to be influential in how children appropriately extend words into syntactic frames. FIT is an acronym meant to capture that the semantic FIT of the lexical ITEM in the TEMPLATE

(or construction) is important. The frequency of the item in the construction and the frequency of the construction itself are both relevant factors as well. Thus, mistakes, like that reported by Bowerman (1982), *she giggled me*, may occur because of the way the child understands the verb to fit into the semantic class. These mistakes may then be suppressed because the child does not hear that particular lexical item, in this case, *giggled*, being used in that template sufficiently often (Ambridge, Pine, & Rowland, 2012; Ambridge, Pine, Rowland, & Chang, 2012). Studies of dense corpora show that children's flexibility in using verbs is directly related to how often children hear those verbs used by caregivers in a variety of frames (Theakston et al., 2015), further emphasizing the role of type and token frequency in a particular child's input and the need to analyze the input to individual children rather than groups.

Languages other than English do not necessarily have such fixed word order, and more information is often carried in the verb morphology. For instance, in Spanish, it is relatively common to omit subjects and to indicate person and number, in addition to tense and aspect, on the verb itself (e.g., *y estaba jugando* = "and I/he/she was playing"). In addition, objects may be indicated via clitics that are attached to the verb rather than pronouns or noun phrases (e.g., *Peinarla* – comb + it (the hair); *Ponérselo* – put + reflexive + it = "Put it on him/herself"). Nonetheless, in child-directed speech, multi-unit sequences do appear to be present at frequencies that children could make use of (Stoll, Abbot-Smith, & Lieven, 2009). How abstractions are formed and what cues children utilize in languages that have more variable word order is an ongoing area of investigation.

## Morphology

Although English is not the ideal language in which to study the acquisition of morphology, given its sparse morphological marking and irregular patterns, much of the early work was exclusively conducted in English. The study of inflectional morphology has been heavily shaped by Brown's (1973) seminal work using naturalistic recordings of three children with the pseudonyms Adam, Eve, and Sarah. The 14 morphemes he identified and the criteria he set forth of accuracy above 90% in obligatory contexts for three consecutive recordings as a definition of mastery have driven the field for over half a century. Based on these criteria, he argued that there was a typical order of acquisition that could be observed, with *-ing*, *in*, *on*, and plural *-s*, acquired very early, followed by irregular past, possessive *-s*, uncontractible copula, articles, and regular forms of past *-ed* and third person singular *-s*, and then finally irregular third person, contractible copula, and both contractible and uncontractible forms of auxiliary *be* are learned. Cross-sectional work by Peter and Jill de Villiers (1972) confirmed this order of acquisition broadly speaking, despite using somewhat different criteria for mastery. They tied the gains in morphological accuracy to increasing mean length of utterance (MLU) rather than to the child's age.

### *Measurement issues*

The use of average accuracy in obligatory contexts as the primary metric for assessing mastery has been challenged. Concerns include that children may be relying on memorized, or chunked, forms rather than spontaneously generating the morphemes in question and that, in the case of composite scores, such as the finite verb morphology composite commonly used in the study of children with developmental language disorder, children may achieve high levels of accuracy through using a single morpheme or a small set of morphemes in highly fixed ways (Hadley & Short, 2005). Since a key hallmark of grammar is its generativity, productivity and diversity have also been carefully examined.

Productivity has been defined in a variety of ways. The earliest approach was one of documenting that the child can apply the morpheme in question to a novel word, as in the well-known wug task (Berko, 1958). In this task, children are presented with novel words to inflect. The novelty ensures that the inflections are not memorized as part of the stem but instead are being applied creatively (*Here is one wug, here is another. There are two*_____; *This man likes to rick. Every day he* _____.). More recent work has sought to quantify the degree to which a child can use the morpheme in a variety of contexts that are not likely to be memorized (Hadley & Short, 2005; Rispoli, Hadley, & Holt, 2009). These approaches generally require use of a certain number of lexical items and consider high frequency, contracted forms, especially those joined with pronouns, to be potentially memorized forms that are not informative and therefore not considered in the score. Thus, in these productivity-based metrics, children are given credit for *The boy is jumping* but not *He's jumping*. Diversity metrics look at the variety of morphemes a child uses within a given paradigm. That is, do they use *am*, *is*, *are*, *was*, and *were*, all different forms of *be*?

One might expect to obtain rather different answers to these different scoring approaches, but, in fact, Brown's original work has stood the test of time, and the results have broadly held. Leonard and colleagues recently evaluated the role that different calculation methods may play in our understanding of the acquisition of tense and agreement morphemes (*am*, *is*, *are*, third person singular *-s*, and past tense *-ed*; Leonard, Haebig, Deevy, & Brown, 2017). They found that the accuracy measures, but not the diversity and productivity measures, were robust to sample size problems. Importantly, all three measures showed similar growth curves when large enough samples were employed.

## *Influences on acquisition*

So how do children learn grammatical markers to begin with? Is there individual variation within the acquisition of grammatical morphology? And why are some morphemes learned before others? It is perhaps easier to answer the second question than the first or the last. Paradigmatic complexity and morphological richness influence cross-linguistic differences in acquisition. Input frequency, phonological form, and the semantic information associated with a grammatical marker also influence when the morpheme is acquired and how accurately it is used. While some children do acquire grammatical morphemes effortlessly and early, morphology is often highlighted as an area of particular difficulty in children with developmental language disorder (Rice & Wexler, 1996). Verb morphology is a good clinical marker in English and other Germanic languages (Bedore & Leonard, 1998; Krok & Leonard, 2015), and agreement morphology is frequency cited as a clinical marker in Romance languages like Spanish and Italian (Bedore & Leonard, 2001; Bortolini et al., 2006; Grinstead et al., 2013).

### *Paradigmatic complexity*

Despite being among the most researched languages, English is a poor language choice for systematically studying morphological inflections due to the sparse morphological marking that it adopts (see Table 14.2). English, for instance, largely employs the bare stem in the present tense (*I jump*, *you jump*, *we jump*, *they jump*), only adding a marker for third person singular cases (*he/she jumps*), and in the past tense there is no differentiation for person, number, or gender. Only number is marked on nouns, and there is no requirement for agreement with adjectives or articles. In contrast, Spanish marks number, person, tense, and mood on all verbs, and gender and number on all articles, nouns, and adjectives. Pronouns indicate case and agreement. Other languages also mark things such as case, evidentiality, and aspect.

*Table 14.2* English morphological paradigm.

| | *Copula present/past* | *Present/past progressive* | *Present habitual* | *Past* |
|---|---|---|---|---|
| I | am/was | am/was jumping | jump | jumped |
| you (singular) | are/were | are/were jumping | jump | jumped |
| he/she/it | is/was | is/was jumping | jumps | jumped |
| we | are/were | are/were jumping | jump | jumped |
| you (plural) | are/were | are/were jumping | jump | jumped |
| they | are/were | are/were jumping | jump | jumped |

One hypothesis about acquisition of morphology is that morphology is acquired earlier and more accurately in languages with rich morphological paradigms in which morphological marking is generally obligatory and generally carries more information than is observed in English. Thus, the relatively protracted acquisition of verb morphology in English is not attested in, say, Italian (Caselli, Casadio, & Bates, 1999; Slobin & Bever, 1982). Another hypothesis is that a highly complex morphological paradigm may in fact overwhelm learners, thereby reducing early accuracy. Consider, for example, the noun paradigm in Lithuanian, which includes number (singular/plural), gender (masculine, feminine), and seven cases, leading to 140 possible combinations, more than 51 of which are unique inflections. An additional 89 phonological forms are repeated at least once in the paradigm. In a study using familiar nouns to assess 4–5-year-olds' abstract knowledge of the paradigm, Savičiūtė and colleagues found that overall accuracy in elicited production probes was approximately 62% correct, with novel nouns showing a lower accuracy (Savičiūtė, Ambridge, & Pine, 2018). This calls into question claims, based primarily on English data, that all children have fully mastered morphological acquisition by age 5 at the latest.

In natural languages, morphological richness and paradigmatic complexity are not independent constructs that can be directly manipulated. Furthermore, richness and complexity may not be well operationalized, making cross-linguistic work all the more challenging (but see Xanthos et al., 2011, for one attempt at characterizing the mean size of the paradigm). However, Hebrew provides an opportunity to consider the role of richness in drawing attention to morphology and the role of complexity in reducing learnability. Hebrew is a morphologically rich language that uses a combination of prefixes, infixes, and suffixes to transform roots into lexical items inflected for a particular tense/ agreement paradigm. For instance, the root *k-t-v* in Hebrew means "to write". If it is placed in a particular binyan, or pattern, it takes on the meaning "to dictate" or "to correspond". These binyanim are not simply the lexicalization of a phonological form; they also carry information such as whether the action should be considered causative or reflexive. Thus, the insertion of a root into a binyan can be productive. Each binyan further has its own conjugation pattern reflecting tense, person, and number. Thus, one would consider Hebrew a morphologically rich language, particularly as compared to English. Hebrew is further interesting because the present and past tense differ rather dramatically in paradigmatic complexity. In the present tense, only number and gender are marked (and in the plural, gender is often collapsed to the masculine form only in spoken language). In the past tense, person, number, and gender are all marked, leading to a much more complex set of markings. In work examining how accurately children with developmental language disorder and their typically developing peers could inflect verbs, Leonard, Dromi, and colleagues found that Hebrew-speaking children

with and without developmental language disorder were generally more accurate at inflecting verbs than their English-speaking counterparts, supporting the hypothesis that morphological richness leads to earlier/more accurate use of morphology. However, Hebrew-speaking children were also much more accurate at present tense than past tense, suggesting that paradigmatic complexity can also affect the learning process (Dromi, Leonard, Adam, & Zadunaisky-Ehrlich, 1999; Dromi, Leonard, & Shteiman, 1993; Rom & Leonard, 1990).

## *Frequency and regularity*

What to count when considering frequency in the acquisition of morphology is an ongoing question (Ambridge, 2010). Much like in argument structure, there is a tension since the most frequent items are not necessarily learned first, and interactions between type and token frequency influence the outcomes. For instance, frequent function words, like *the* or *is*, are not among the first 100 words that children learn, but are among the earliest *function* words acquired (Goodman, Dale, & Li, 2008). As with the FIT hypothesis's application to argument structure, in morphology both semantics and frequency matter. Similarly, more frequent phonological variants of a morpheme tend to be acquired earlier than their less frequent counterparts, even if the less frequent form is more phonologically salient. Consider, for instance, the allomorphs for past tense *-t*, *-d*, and *-id*; *-t* and *-d* tend to be acquired earlier even though the syllabic allomorph is more phonologically salient (Berko, 1958). That said, work on more morphologically rich languages indicates that frequency is not the sole factor. Returning to the work on Lithuanian noun inflections by Savičiūtė and colleagues described previously, it is worth noting that the most common errors were near-misses in which, say, a singular form was replaced by an otherwise correct plural form, or a feminine form was replaced by an otherwise correct masculine form, rather than wholesale substitution of the most frequent form for all less frequent forms (Savičiūtė et al., 2018). This was also the case in Leonard's work on Hebrew and Spanish (Bedore & Leonard, 2001; Dromi et al., 1999; Owen, Dromi, & Leonard, 2001), suggesting that this is a consistent pattern across nouns and verbs in morphologically rich languages. Examination of languages with richer morphological paradigms is important because the error patterns allow us to add nuance to (and possibly entirely shift) the way that we think of the role of frequency in language learning.

That said, the question of frequency in morphology is worthy of deeper explanation since it often interacts with other relevant variables such as regularity. In fact, the questions of how these two components interact sparked the single-route/dual-route debate: Are most words formed by the application of a rule, with high frequency/irregular forms serving as exceptions that are retrieved as memorized lexical items, thereby blocking the application of the rules associated with regular inflection? Or is there some single system by which the patterns and regularities of irregular and regular inflection are learned?

This debate is most commonly illustrated in the area of English past tense. It is helpful to review the trajectory of acquisition before delving into the explanations (Kuczaj, 1977; Matthews & Theakston, 2006; Plunkett & Marchman, 1991). In English past tense, early accuracy is observed with high frequency irregulars (e.g., *went*, *bought*, *sat*, *rang*) as well as high frequency regular forms (e.g., *wanted*, *used*, *worked*). This period of high accuracy is followed by a large drop in accuracy and then a gradual rise, eventually attaining again extremely high levels of accuracy – the U-shaped developmental curve. When accuracy drops, are we observing a period of regression? Researchers speculate that the small number of highly accurate words are verbs that are initially learned as unanalyzed wholes. The child's total vocabulary is small, and their verb vocabulary is even smaller. At this time point, words generally appear in a single form

only – that is, if a child knows the word *found*, or *jumping*, they are unlikely to also use the words *find*, *finding*, and *finds* or *jumped*, *jumps*, and *jump*. As the child gets older, their verb vocabulary grows and is accompanied by a decline in accurate morphological marking (Plunkett & Marchman, 1991). This dip in accuracy reflects a sharp increase in the number of regular verbs the child produces, with the child frequently producing bare stems instead of inflected forms. Irregulars may be produced both in the bare and in the inflected forms. Following this period of omission in nearly all forms, children begin to accurately inflect regular forms with *-ed*, but make mistakes with irregulars, this time overgeneralizing rather than omitting. Thus, we see productions such as *wented or goed* as the primary mistakes. Finally, children seem to stabilize at high levels of accuracy, getting both irregulars and regulars correct most of the time.

By the dual-route (words and rules) account, children have a set of words that they produce as memorized wholes, which includes high frequency regulars and nearly all irregulars, which are able to maintain their irregular status in the language by virtue of also being highly frequent (Pinker & Ullman, 2002). Less frequent forms are produced in a combinatorial way, applying the rule "add *-ed*", which then undergoes phonological changes resulting in the relevant allomorph. The challenge for this account is to determine when rules should be applied and when highly frequent forms should be directly retrieved.

According to the single-route account, children learn that certain phonological patterns change in systematic ways. So irregular word families may share a phonological form in the stem (e.g., *-in* as in *ring*, *sing*, *sink*, *drink*, *begin*), and then all of these words undergo a similar change (e.g., to *-an*, as in *rang*, *sang*, *sank*, *drank*, *began*). The number and frequency of words that make up these families help to determine how likely it is that the pattern will be applied broadly to new words. For instance, *swing*, *swang* or *bring*, *brang* are examples of productive, non-standard applications of the *-in/-an* pattern. Some word families are very small, consisting of a single, high frequency word (e.g., *go/went*). Other families are large, incorporating highly diverse word forms, and extremely productive such as the *-t/-d/-id* allomorphs associated with the regular form. Thus, when the system is presented with any word, it attempts to pattern match the phonological form to an existing phonological template. Irregular forms persist because their type/token frequencies make them likely to be matched. The regular form is so productive because the diversity of the stem pattern makes it an attractive place for patterns without clear matches to land (Plunkett & Marchman, 1991).

When only English is examined, the type of evidence provided to differentiate these approaches has always been difficult to interpret because of the confounding effects of frequency and regularity. Experiments that elicit verbs under timed conditions have found that the reaction times for irregulars are much faster than those for regular forms, in principle falling on the side of dual-route approaches (Alegre & Gordon, 1999). However, more frequent stimuli generally elicit faster reaction times; thus, highly frequent (potentially memorized) regular forms also should be faster and are not (Marslen-Wilson & Tyler, 1998). Similarly, the broad based productivity of the regular form is consistent with dual-route approaches. In general, dual-route (words and rules) approaches were dominant because researchers could not imagine that the brain could operate using an alternative approach. In 1986, Rumelhart and McClelland produced a computational model that provided proof of concept that a single-route approach could explain the behavioral phenomena (Rumelhart, McClelland, & PDP Research Group, 1986). One advantage of this model and its refinements was that it accounted for the U-shaped curve, and that incorporating changes in verb vocabulary size across the course of development led to changes in the model's accuracy that mirrored development. Though these models have been critiqued for the fact that their error patterns are not completely consistent with

children's errors, they have largely revolutionized the conversation about how the brain accomplishes the task of inflecting words accurately. Much of the debate has shifted to which of several pattern matching approaches are accurate rather than discussion of whether single-route approaches are valid.

Although somewhat dated, this debate is a useful illustrative example for several reasons. First, it highlights that frequency is a key variable in acquisition, but that frequency interacts with other information, like the regularity of the phonological patterns, much as frequency interacts with the syntactic frame with regard to argument structure. The systematicity of the phonological patterns both for the stems and for the inflections varies cross-linguistically, further highlighting the fact that broad generalizations about acquisition patterns are possible, but only if one can accurately characterize the relevant information the child must attend to in order to learn the inflectional pattern. This brings us to the second point, which is that determining what is being counted is critical for a successful account of the role of frequency in learning (Ambridge, 2010). In this case, we consider the relative frequency of the inflected form as compared to its stem form and as compared to all other inflected forms, the size of the phonological family as compared to other phonological families, and the frequency of the elements within each phonological family. We also must account for how these various numbers change over developmental time. A complex task indeed! Finally, this extended discussion illustrates the value of computational models for our understanding of these complex phenomena. The process of specifying how these various quantitative values are implemented in a model commits the researcher to particular accounts and explanations in a way that other approaches do not. The match, or in some cases, the mismatch, between the model and the behavioral phenomena leads to the development of new hypotheses and refinements that are useful.

Returning to the points about the role of frequency as a key variable that must be measured both in absolute terms and relative to other forms and about the role of computational modeling in shaping our thinking, new approaches have focused on competition between forms as one explanation. For instance, Matthews and Theakston (2006) showed that the ratio of the stem to the inflected form for irregular plurals influenced the error rates. They contrasted examples in which the ratio of the irregular plural to the stem is more and less frequent (frequencies in child-directed speech – mouse:440, mice:61; tooth:83, teeth:470), with children demonstrating higher accuracy for *teeth* than *mice* at age 5. They argue that it is the different levels of competition between *mouse/mice* and *tooth/teeth* that lead to these different accuracy rates. Similar findings are available in English for third person singular *-s* (Räsänen, Ambridge, & Pine, 2014) and for regular and irregular past tense *-ed* (Matthews & Theakston, 2006). Although overall accuracy rates are much reduced, children with developmental language disorder appear to rely on relative frequency of the inflected and bare forms to a similar degree as children with typical language (Owen Van Horne & Green Fager, 2015).

Japanese is an agglutinating language that therefore allows for direct assessment of the relative frequencies of different verb stem + inflection combinations and their effect on children's accuracy. Tatsumi, Ambridge, and Pine (2018) asked children to produce simple past and complex past (stative and completive) forms. They compared accuracy on the forms to their relative use in child-directed speech and found that for the completive forms the children's accuracy was well aligned with how frequently the verb was heard in the completive form relative to how often the completive form occurs in the general input. The stative forms did not show similar relationships, but this may have been due to a selection bias in the verbs tested rather than the lack of a relationship. This study draws attention to the way that languages with different typologies can help inform our understanding of the role of frequency in language learning.

## Phonological salience

Another hypothesis about acquisition has been that those elements that are more easily perceived will be acquired earlier. Take, for example, the question of why the English plural *-s* is acquired much earlier and with greater accuracy levels than its homophonous counterpart, third person singular *-s*. Several reasons have been put forth that are not perceptually grounded, including the semantic complexity and transparency of the markers. That is, third person singular *-s* combines information about tense/aspect, person, and number into a single marker, while plural *-s* only reflects number. In addition, plural *-s* is 5 times more frequent overall than third person singular *-s* so it may be acquired earlier simply on the strength of how often it occurs in the input. Critically, however, plural *-s* is not just more frequent in general; it is 16 times more frequent in sentence final position, a location that leads to lengthening of the /s/, making it more perceptually salient (e.g., the surface account; Hsieh, Leonard, & Swanson, 1999; Sundara, 2017). Leonard and colleagues argued that it was for this reason that plural *-s* is acquired earlier than other grammatical markers in English and is relatively preserved in children with developmental language disorder (Bortolini & Leonard, 1996; Leonard, 1989).

Originally, this was entirely a story about morpheme perception, with researchers arguing that perceptual salience was the primary factor influencing acquisition. Over the last 10 years, in a highly programmatic line of work, the Demuth lab has shown that production accuracy is also influenced by the same elements that influence perceptual salience: sentence position, phonological complexity, and morpheme type (Mealings & Demuth, 2014; Song, Demuth, Shattuck-Hufnagel, & Ménard, 2013; Song, Sundara, & Demuth, 2009; Sundara, Demuth, & Kuhl, 2011; Theodore, Demuth, & Shattuck-Hufnagel, 2011). That is, children's articulatory skills, not just the ease with which these morphemes can be perceived, are critical aspects influencing acquisition. Similar findings from past tense *-ed* indicating reduced imitative accuracy in sentence medial, as opposed to sentence final, contexts suggest that this is not unique to sibilants but rather something that might influence accuracy more broadly for morphemes that are of short duration or reduced phonological salience (Dalal & Loeb, 2005). Although not directly documented in this line of research, one might infer that children with better speech production skills are better at producing grammatical morphemes, a finding that is corroborated by studies of children with speech sound disorders (McLeod et al., 2017). Examination of the overall articulatory profiles of children judged to be typical who are younger than those in McLeod and colleagues' work would be a useful contribution to this line of work.

## Semantics

Grammar, and especially morphology, is often viewed as being relatively devoid of semantic content. This focus on pattern acquisition has led to an emphasis on the role of variability in grammar learning (Plante et al., 2014; Hadley, 2014) and the use of artificial grammar learning paradigms, in which children and adults are trained on auditory patterns that contain grammatical elements that are not linked to meaning in any fashion (e.g., Grunow, Spaulding, Gómez, & Plante, 2006; Misyak & Christiansen, 2012; Onnis, Destrebecqz, Christiansen, Chater, & Cleeremans, 2015; von Koss Torkildsen, Dailey, Aguilar, Gómez, & Plante, 2013). Nonetheless, a key element of grammar is that it does enable us to communicate meaning that is not communicable through a simple string of words. Thus, one might wonder whether the meaning of the morphemes and their alignment with the words that they are inflecting influences their acquisition.

One area in which this alignment of meaning can be assessed is in the case of tense and aspect. Tense is information about when something happened relative to speaking time. For

instance, an event that ended prior to the speaking time would be in the past tense. Aspect is information about event duration and repetition. For instance, whether an event was ongoing or completed in the past would be a reflection of aspect. Aspect can be further divided into lexical aspect, or information about the inherent time of an event, and morphological aspect, or information about how long an event tends to take (see Comrie, 1976, for a complete description). Events that are inherently completed (e.g., *close*, *drop*, *die*) are referred to as having telic aspect. Ongoing events (such as *wiggling*, *growing*, *writing*) are referred to as being atelic. One can inflect a telic verb like *close the door* in the past tense (*closed*), reinforcing the completed nature of the event, or add morphological information about the duration of the event that modifies the event to be more ongoing (*was closing the door*). In some languages tense and aspect are explicitly marked using separate morphological forms, and in others, like English, they are related such that the use of the third person singular *-s* form tends to reflect both present tense and habitual aspect. Similarly, the use of the past tense *-ed* form tends to reflect both pastness and completedness from an aspectual standpoint.

Li and Shirai (2000) considered how lexical aspect and morphological tense interact in English, Japanese, and Chinese and then further explored these relationships in a computational model. To illustrate with English, they considered, for instance, how inherently completed events are realized in simple past, third person singular *-s*, and present/past progressive forms (*die*: *died*, *dies*, *is/was dying*). They found that children's earliest productions of inflected verbs reflect cases in which lexical aspect is more closely aligned with the tense-related morphological marker being produced, such as atelic, activity verbs paired with present progressive inflections or telic, accomplishment verbs paired with past tense information. Children show evidence of being able to generalize their use of morphological inflections to verbs with less-aligned aspectual information later in development, perhaps due to increased exposure to these verbs as they get older. One innovation was that Li and Shirai were especially attentive to how lexicon size and composition changed over developmental time across these three languages. Their findings have been further extended to adult second language learners. Wulff and colleagues demonstrated that the well-aligned verb + inflection combinations were more common in corpus data than mis-aligned cases and that adult learners of English tended to be most accurate at inflecting the highly aligned combinations, just like children (Wulff, Ellis, Bardovi-Harlig, & Leblanc, 2009). This same finding holds broadly for older typical children and children with developmental language disorder (Owen Van Horne & Green Fager, 2015). Using a treatment study, my own lab has confirmed the hypothesis that it is exposure to the mismatch between tense and aspect that leads to the generalization of morphemes rather than simply the passage of developmental time or a larger lexicon. Furthermore, we showed that it is possible to accelerate acquisition in children with developmental language disorder by exposing them to a certain input pattern, additional evidence that language acquisition may be influenced by the input (Owen Van Horne, Fey, & Curran, 2017).

## *Interactions between semantics, phonology, and frequency*

Some studies explicitly assess the relative contributions of the factors described above to the use of grammatical morphology. For instance, a few studies have examined interactions between aspect and phonology. Johnson and Morris (2007) demonstrated that typical 2-year-olds were more accurate at inflecting a verb like *chewed up a green grape* when the verb was telic and ended in a vowel than when faced with the same verb in an atelic situation, such as *chewed a piece of gum*. They were least accurate in cases in which the verb ended with an obstruent consonant *and* was in an atelic situation, as with *she skipped on the rug*. In a retrospective analysis of another

data set, Owen Van Horne and Green Fager (2015) confirmed these findings in older typical children and children with developmental language disorder, demonstrating that even for older children, phonological form, lexical frequency in the inflected form, and independent ratings of telicity all uniquely, and approximately equally, influenced accuracy of using regular past tense *-ed*. This study is important because it statistically corrects for the fact that verb phrases like *chewed up* are more likely to be heard in the past tense whereas ongoing verbs (e.g., *skipped*) are more likely to be heard in another form, such as the present progressive.

The relationship between phonological complexity and inflectional complexity is also worthy of study. In the study of Japanese simple and complex past inflection described earlier, the role of phonology as compared to frequency of the forms in the input was also considered. In many languages phonological complexity and frequency are confounded because more complex inflections tend to be longer and less frequent. Because Japanese is agglutinating it was possible to dissociate the role of frequency from the number of syllables in the word form. Tatsumi and colleagues (2018) found that the relative frequency of the stem in a complex form was a stronger predictor of accuracy, overriding any difficulty that might have come from the fact that the complex form was longer than the simple form.

Type frequency is the frequency of an individual pattern or group of words. In the study of Lithuanian noun inflections reported previously, the hypothesis that type frequency might influence accuracy was also assessed. In this case, type frequency was defined as the phonological pattern of the stem relative to the inflectional form used, and it was measured via phonological neighborhood density (Savičiūtė et al., 2018). This was important given how often some inflectional forms reoccurred in the highly complex pattern. More frequent types were more accurately used than less frequent types, even above and beyond the influence of individual word frequency, a simpler measure that did not consider phonological type.

What these three studies especially illustrate is the need to develop careful hypotheses about how different elements known to influence acquisition might be deployed in relation to each other. This is especially difficult work to do because it requires deep understanding of possible language acquisition mechanisms, language typology, and the ability to actually realize the contrasts in a natural language.

## Complex syntax

While there may be some dispute as to whether there are meaningful individual differences in the acquisition of simple syntax, the influence of socioeconomic status, vocabulary size, and processing capacity clearly re-emerge when discussing complex syntax acquisition. Complex syntax is most often defined as sentences that consist of a main clause with one or more associated subordinate clauses (finite and nonfinite complement clauses, relative clauses, adverbial clauses; see Table 14.3); however, discussions of complex syntax often add in ancillary areas such as compound sentences and sentences that require non-canonical word order or movement (e.g., object *wh*-questions, passives, and, again, relative clauses). The amount and variety of complex syntax a child produces are heavily influenced by the amount and variety of complex sentences the child hears, which is in turn correlated with the education level of the caregiver (Huttenlocher et al., 2002). Hearing complex sentences in books increases the ability of children to comprehend and produce those sentence types (Hesketh, Serratrice, & Ashworth, 2016; Vasilyeva, Huttenlocher, & Waterfall, 2006). Although use of complex syntax appears to be somewhat invariant across dialects of English, increased use may be associated with increased dialect density and thereby be some measure of language competence (Craig & Washington, 1994). Young children learning English as an additional language seem to benefit most from complex syntax

*Table 14.3* Types of English sentence frames.

| | | | *Example 1* | *Example 2* |
|---|---|---|---|---|
| Simple sentences | Intransitive | S + V | He laughed | She ate |
| | Transitive | S + V + O | He kicked the door | She ate the sandwich |
| | Ditransitive | S + V + IO + DO or<br>S + V + DO + PP | He kicked me the ball | She sent the letter to the man |
| Complex sentences | Complement clause (finite) | S + V + (that) + sentence | She thought that he was happy | He knew the sky was blue |
| | | S + V + to + V | She wanted to go home | He need to climb a tree |
| | Complement clause (nonfinite) | S + V + N + to + V | She wanted him to go home | She told him to wear a hat |
| | | S + V + N + V + ing | She saw him jumping | He heard her calling |
| *Subordination* | Adverbial (conditional) | If + sentence, (then) + sentence | If it is hot, then we will wear hats | We will go home if you get tired. |
| | Adverbial (causal) | Because, so | Because the wind blew, the kite went up | The wind blew, so the kite went up |
| | *Wh*-questions | Subject *wh*- question | Who is hitting him? | What was falling? |
| | | Object *wh*- question | Who is she hitting? | What is he washing? |
| | | *Get* passive | It got broken | The wagon got dropped by the boy |
| *Non-canonical word order* | Passive | *Be* passive | The sandwich was eaten. | The car was crashed by the lady |
| | | Actional passive | The tire was kicked | The door got closed |
| | | Adjectival passive | The door was closed | The toy was mended |
| | Relative clause | Subject gap, modifying subject of sentence | The person who puts them on has to clean them | The dog that jumps over the pig bumps into the lion |
| | | Object gap, modifying the object of the sentence | Look at all the chairs (that) Peter's got | The dog stands on the horse that the giraffe jumps over |
| | | Object gap, modifying the subject of the sentence | The girl that the boy kissed went home | The lion that the horse bumps into jumps over the giraffe |
| | | Subject gap, modifying the object of the sentence | It's a dog that goes woof | The pig bumps into the horse that jumps over the giraffe |

*Note:* S = subject, V = verb, O = object, IO = indirect object, DO = direct object, PP = prepositional phrase. Elements in parentheses are optional.

*Source:* Relative Clause Taxonomy and the second column of relative clause examples are from Sheldon, 1974.

input when they already have an established lexicon and have had access to simple sentences in English. At that point, being paired with a teacher who uses more syntactic complexity leads to greater growth (Bowers & Vasilyeva, 2011).

## *Subordination*

Complex syntactic forms are often mistakenly assumed to be a later attainment, only observable in school-age children and adults. In fact, there is ample evidence that very young children produce multi-clause utterances as young as 2;6 (Bloom, Lahey, Hood, Lifter, & Fiess, 1980; Diessel, 2004; Limber, 1973). Like the slot-frame grammars described previously, complex syntax production appears to begin in a simplified and highly lexically specific way. For instance, the earliest examples of relative clauses are presentational copulas (e.g., *it a dog go woof*; Diessel & Tomasello, 2000), and early finite complement clauses tend to rely on the words *think* and *know*, with the main clause used more like an adverb than a true complement taking verb (e.g., *daddy's home, I think*; *it's hot in here, ya' know*; Diessel & Tomasello, 2001). Evidence that relative clauses are used in abstract ways include a shift toward using more transitive relative clauses, thereby requiring an additional argument, and the increased use of object relative clauses, which generally indicate a shift toward expressing two propositions (Diessel & Tomasello, 2000). Diessel and Tomasello (2001) similarly argue that productive use of complement clauses is only evident when one can see the use of the main clause verb with a non-first/second person subject or in multiple tenses (e.g., *he thought that the sky was green*; *she knew that the girl went home*), making it clear that two propositions are being expressed. Use of the complement taking verb in a counterfactual also provides evidence that it is being used in a fully productive format (e.g., *She thought he was at home, but he wasn't*). Typically, when children begin using these forms productively, the clauses follow a canonical order such that the main clause precedes the complement clause; when it is used in a more adverbial form, the order of clauses may vary.

Other complex forms also appear to build up from smaller pieces, though the evidence of formulaic forms is not as readily available. In some cases, the use of smaller pieces first has been taken as evidence of underlying knowledge that is masked by performance limitations. However, item-based or usage-based accounts tend to instead attribute this process of building up to children's ability to grasp and utilize chunks of a certain size and the fact that they are more likely to utilize forms in ways that are commonly heard in the input (Ambridge & Lieven, 2011; Diessel, 2004). For instance, when learning to produce causal adverbials, children may initially produce the causal statement (*because he was happy*) in response to a *why* question and only later produce both clauses. In fact, in child-directed discourse, *why* and *how come* questions posed by either the child or the adult are commonly answered by a single clause utterance. Highly familiar causal events are described correctly first, with those that are related to emotion or motivation being particularly early and particularly common in conversations with young children (e.g., *he was sad, so he cried*) (Bloom et al., 1980; French & Nelson, 1985). Similarly, children initially describe events correctly only if the order of the clauses follows canonical real-world events (French, 1988). Thus, a sentence like *she opened the door because the doorbell rang* is more likely to be produced correctly earlier than *she rang the doorbell because the door opened*. This is true not just for causal adverbials, but for other types of adverbials as well, such as conditional (*if/then*) and temporal (*before/after*) adverbials (Clark, 1971; de Ruiter, Theakston, Brandt, Lieven, 2018; Diessel, 2008).

Surprisingly, evidence of productive syntax use often follows only a few months after the first formulaic production. Even so, links between complex syntax and the lexicon are apparent into adulthood. Finite and nonfinite complement clauses are somewhat obviously tied to

the lexicon since the subordinate clause is an argument of the verb. These clauses primarily co-occur with verbs of perception, cognition, communication, and desire. Kidd and colleagues carried out a study in which they asked children to repeat different types of complement clauses with high and low frequency verbs used as the main verb (Kidd, Lieven, & Tomasello, 2006). Verb frequency alone did not predict the outcome. Rather, children were more accurate when the main verb tended to occur in sentences with that type of complement clause, with their most common error being switching a low frequency verb for a higher frequency verb associated with that sentence frame (e.g., replacing *bet* with *think*). Similarly, the variety of cognitive verbs a child knows influences their use of complement clauses and in particular the variety of verbs that children are willing to use spontaneously as main verbs. Critically, children produced the same number of complement taking verbs in spontaneous language samples, but only those with high vocabularies actually used these types of verbs in complex forms (Owen Van Horne & Lin, 2011).

Although the cognitive and communication verbs that take finite complement clauses tend to be fairly uniform in terms of the syntactic frames they can occur in, those that are associated with nonfinite complement clauses tend to occur in a variety of lexically specific frames (e.g., *She hoped for him to call her*; *He made it fall*; *They saw her jumping*; *She wanted to eat ice cream*; *He told her to sit down*; *He promised her to go home soon*). These sentences vary in structure and also in who the agent of the second clause is, even in sentences with nearly identical surface structures. These rules are highly idiosyncratic and lexically specific and are relatively late-acquired. Thus, even though finite and nonfinite complements are observed spontaneously as young as 2;6, the full suite of structures are not produced and understood by typical 5- to 9-year-olds (Chomsky, 1969; Eisenberg & Cairns, 1994). Similar challenges arise with regard to co-reference in adverbial clauses, suggesting that while children's production in spontaneous speech may make it appear as if they have mastered a wide variety of complex syntactic frames very young, the details may actually take quite some time to work out (Cairns, McDaniel, Hsu, & Rapp, 1994).

## *Non-canonical word order*

Object relative clauses and passives, two structures that adopt non-canonical word order, serve to further illustrate three things: the fact that syntactic acquisition continues into adulthood, that input plays an important role in developing these forms over the lifespan, and that high frequency components, like pronouns, may serve as anchors. Because object relative clauses (e.g., *the girl who the horse loved ate an apple*) and passives (e.g., *the apple was dropped by the girl*) both place the patient in the subject position of the sentence, children must be attentive to things like word order and the presence of grammatical markers that indicate that the sentence should be interpreted differently than a simple active sentence that employs canonical word order. In English, those cues include the addition of a *by* phrase, the presence of auxiliary verbs (*get*, *be*), the use of a participial form (*-en* and *-ed* forms of verbs), the use of a relativizer (e.g., *who*, *that*, *which*), or the fact that two nouns occur sequentially in a sentence when the relativizer is omitted.

Relative clause acquisition in spontaneous speech is one of the few forms that shows development across the lifespan, with continued increases in use into middle adulthood (Nippold, Hesketh, Duthie, & Mansfield, 2005). This is consistent with work showing that increased exposure to non-canonical sentences in text leads to increased use of relative clauses in both middle-grade children (Montag & MacDonald, 2015) and adults (Wells, Christiansen, Race, Acheson, & MacDonald, 2009). Critical differences in what kinds of relative clauses children easily produce can be tied to schema from the input (Fox & Thompson, 1990; Reali & Christiansen, 2007; Roland, Dick, & Elman, 2007). Subject relative clauses closely mirror transitive forms in their

interpretation and tend to modify animate nouns (e.g., *the girl who watered the plants dropped the watering can*). Object relatives tend to describe inanimate objects and relate the object to ongoing conversation with reference to a pronoun (e.g., *the book that she read was lost*). Children largely follow this same pattern in their spontaneous language (Diessel, 2009; Kidd, Brandt, Lieven, & Tomasello, 2007). In imitation tasks, children also mirrored the input structure (Brandt, Kidd, Lieven, & Tomasello, 2009).

Like relative clauses, the acquisition of passives seems to depend on their frequency in the input (Allen & Crago, 1996; Demuth, 1989, 1990; Demuth, Moloi, & Machobane, 2010), with some characteristics such as the type of morphological marker used also influencing accuracy in some cases. In a particularly large study of the comprehension of passives across 11 languages, Armon-Lotem and colleagues (Armon-Lotem et al., 2016) found that in most of the languages studied, 5-year-old children comprehend both short passives (*he got kicked*) and simple active sentences about equally. Full passives were more challenging, suggesting that children may have been relying on an adjectival reading of the passive (e.g., *it was broken/eaten/fixed*) rather than actually interpreting these sentences as true passives (e.g., *it got broken/eaten/fixed by someone*).

As with relatives, differences in acquisition patterns can be traced back to input patterns. In English, at least, *get* passives tend to be interpreted as having a more agentive reading than *be* passives (contrast: *the wagon got broken* vs. *the wagon was broken*) and cannot be interpreted adjectivally. Budwig (1990) reports that children maintain this distinction in their own productions. Further work shows that stative passives (*was seen*) are more difficult than actional passives (*was dropped*), further reflecting patterns in the input (Maratsos, Fox, Becker, & Chalkley, 1985; Gordon & Chafetz, 1990). Thus, we see that even in these more advanced syntactic frames, the particular characteristics of the input, and the particular the role of the verb within the sentence, drive acquisition patterns.

## Conclusion

The ability to produce combinatorial constructions that communicate about abstract concepts is an amazing skill that most humans accomplish with limited effort. Nonetheless, there is individual variation in the onset of two-word phrases, the accurate use of morphology, and the production of complex sentences. Much of this variation, as well as patterns of production associated with simple sentences, can be traced back to patterns in the input. The fact that particular qualities of the input may enhance or accelerate the acquisition of syntactic frames is good news for those who are interested in assisting children who are at-risk for delayed language development for one reason or another. A productive pattern of future work would be that which both examines the elements important for learning syntax and identifies effective teaching practices to support children for whom language learning and use are barriers to success.

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# 15

# LEARNING LANGUAGE IS LEARNING TYPOLOGY

## Acquisition of argument structure and relative clauses in typologically diverse languages

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As of 2018, there are 7,097 living languages worldwide (Simons & Fennig, 2018). Though current studies of language acquisition cover only a low proportion of these languages, studies on typologically diverse languages have provided valuable knowledge and broadened our perspective about children's language acquisition. We now have adequate evidence to conclude that learners of a fixed word order language cannot be generalized to understand and assess how children exposed to flexible word order languages behave in forming basic meanings such as who-did-what-to-whom in simple sentences. The variation of linguistic devices across different languages is even more pronounced in regard to complex language that involves combinations of clauses. In this chapter we will cover both simple and complex language constructions, and evaluate crosslinguistic research on monolingual children's acquisition of 1. argument structure and 2. relative clauses.

The knowledge of argument structure is particularly essential for children to make sense of the world, to break into the language system, and to communicate effectively about this world. This is primarily because argument structure is a linguistic phenomenon whereby the meaning of action- or state-denoting words (usually the verbs; e.g., "to chase") is completed by other lexical items (usually the subject and the object; "the dog" and "the cat" as in "the dog chased the cat"). Crosslinguistic studies have demonstrated that different languages configure these form-function mappings in different ways. Therefore, children learning diverse languages may need to utilize different arrays of cues to argument structure based on their ambient language. Our primary focus will therefore be on the learning of argument structure in the first part. Our second focus is on relative clauses (e.g., *the dog that chased the cat*) as a representative case of complex language structures. The investigation of how children learning typologically diverse languages acquire relative clauses differently builds on crosslinguistic differences that emerge as a function of the structure of the language being acquired (e.g., head-finality) and the characteristics of the speech directed to the child. Thus, we aim to provide an account of how current crosslinguistic research on the acquisition of simple and complex language supports or challenges established ideas about language development. We suggest that a change of focus for crosslinguistic research from universality to linguistic diversity is fruitful to identify the underlying mechanisms of language development (Dąbrowska, 2015).

## Learning argument structure

The key objective of language learning is to comprehend components of events and achieve effective verbal communication about these events. Development of language requires an understanding of the action and its participants, mainly the doer of the action (i.e., agent) and the undergoer of the action (i.e., patient), as well as learning how to map action understanding into linguistic expressions. For example, transitive verbs require an agent and a patient (e.g., "the boy eats the cake"), while ditransitive verbs require an additional participant, which is the recipient (e.g., "the boy gives the cake to the girl"). The knowledge of the semantic and syntactic relations of these participants in events to the verb constitutes the knowledge of argument structure.

Learning argument structure is crucial for the developing child, as the task in language acquisition is to establish the link between linguistic form and action/event understanding (Goldberg, Casenhiser, & Sethuraman, 2004). Crosslinguistic research has shown that different languages have different configurations of form-function mappings and that children may rely on various cues and strategies to break into the argument structure of their ambient language. These cues include animacy (Chan, Meints, Lieven, & Tomasello, 2009; Tanaka & Shirai, 2014), word order (Gertner, Fisher, & Eisengart, 2006), nominal case markers (Dittmar, Abbot-Smith, Lieven, & Tomasello, 2008), and verbal morphology (Demuth, Machobane, & Moloi, 2003). Children utilize some language-specific combination of these cues when learning the argument structure, which indicates that different strategies of form-function mapping might be employed by children based on the characteristics of the language being learned (Slobin & Bever, 1982). Moreover, these strategies may change during the course of language acquisition (Bates & MacWhinney, 1989). In this section, we first provide evidence for the utilization of argument structure cues in English-learning children, which is followed by how children learning typologically different languages acquire argument structure knowledge. We will refer to the construct *cue validity* of the Competition Model framework for explaining these typological differences (Bates & MacWhinney, 1989).

Word order has long been demonstrated to be an important cue for English-learning children's understanding of argument structure (Hirsh-Pasek & Golinkoff, 1996a). It has been shown that English-learning children use the canonical word order of their language to identify agents and patients of the verb before their second birthday. For instance, using the intermodal preferential looking paradigm (IPLP; Golinkoff, Hirsh-Pasek, Cauley, & Gordon, 1987), where children's looks to correct versus incorrect scenes were monitored in relation to the sentence they heard, Hirsh-Pasek and Golinkoff (1996b) showed that 17-month-old infants could use word order to correctly identify reversible agent-patient familiar actions in which the agent and the patient are equally likely to perform the action (e.g., "Big Bird is tickling Cookie Monster" versus "Cookie Monster is tickling Big Bird"). Gertner and colleagues (2006) further showed that 21-month-old infants could use word order to identify argument structure without relying on verb meaning. Infants in this study were able to recognize reversible agent-patient unfamiliar actions labeled with novel verbs. Nevertheless, other researchers proposed that children initially relied on linguistic input to learn the argument structure of specific verbs, and thus the acquisition of argument structure knowledge took place on a verb-by-verb basis (Verb Island Hypothesis; Tomasello, 1992). For instance, Akhtar and Tomasello (1997) showed that 2-year-old children's performance was at chance when they were asked to act out a novel action (e.g., "Make Big Bird *dack* Cookie Monster") that had previously been demonstrated in isolation (without a subject-verb-object frame; e.g., "This is called *dacking*"). This study evidenced that English-learning children's understanding of word order as a marker to agent-patient relations

is likely to be verb-specific rather than verb-general, a developmental phase observed up until age 4 (Akhtar, 1999).

More recently, Chan and colleagues tested the same English-learning children from three age groups (2;0, 2;9, and 3;5) in both act-out (acting out the actions demonstrated) and IPLP tasks using familiar and novel verbs (Chan, Meints, Lieven, & Tomasello, 2010). Their results showed that children at 2;0 did not comprehend word order with novel verbs in either task, while displaying competence with familiar verbs in the IPLP task. The two older groups were successful in comprehending word order in the two verb conditions and in both tasks. Nevertheless, the performance of children at 2;9 was better with the familiar verbs than with the novel verbs in the act-out task. Using two different paradigms, the findings of Chan and colleagues provided further support for the idea that abstract representations for canonical word order as a cue to argument structure emerge gradually as children generalize from verb-based exemplars with accumulating linguistic evidence derived from the input. Indeed, Cameron-Faulkner, Lieven, and Tomasello (2003) showed that the canonical word order in English-speaking mothers' child-directed speech did not prove word order to be a highly available cue at early ages. This is because only about 15% of mothers' utterances to children (ages ranged between 1;9 and 2;6) had the subject-verb-object (SVO) form, while the remaining 85% were composed of questions, imperatives, copulas, and sentence fragments (see Bates & MacWhinney, 1989; Brandt, Lieven, & Tomasello, 2016, for cue availability and reliability).

Crosslinguistic research with diverse languages, on the other hand, provides insightful findings indicating that 1. reliance on linguistic concepts and constructs based on research in English is not always useful for explaining children's learning of argument structure in typologically different languages, and 2. the specific ways in which cues to argument structure that are not directly available for a relatively rigid word order language like English are utilized should be evaluated. In the early 1980s, Slobin and Bever (1982) conducted a study comparing monolingual children aged 2;0 to 4;4 learning English, Turkish, Italian, or Serbo-Croatian. The results of their act-out study indicated that children learning typologically different languages established language-specific combinations of cues to argument structure. For instance, Turkish-learning children demonstrated a reliance on a combination of nominal case markers and canonical word order. Moreover, Turkish-learning children successfully utilized inflectional morphology for extraction of sentence meaning almost 6 months earlier than English-learning children's utilization of word order. This was probably because of the low availability of canonical word order for English-learning children as a cue to argument structure at early ages such as 2 years (Cameron-Faulkner et al., 2003) and the relatively high overall validity of Turkish case markers (especially the accusative marker; MacWhinney, Osmán-Sági, & Slobin, 1991). In a more recent study using IPLP with 1- to 3-year-old children learning Turkish, English, and Mandarin Chinese, Candan and colleagues (2012) showed that although all children were able to match the correct scenes with the typical word order of their languages, Turkish children displayed more uncertainty compared to English children, indicated by more frequent switches in their looks between the two scenes (Candan et al., 2012). As such, young Turkish-learning children appear to be able to utilize the canonical word order frame, but do not consider it as a valid cue to argument structure compared to their English-learning peers. This was most likely due to the relatively flexible word order of Turkish. In fact, only 48% of utterances in Turkish child-directed speech have the canonical subject-object-verb (SOV) word order in constructions where there are two nouns and a verb (Slobin & Bever, 1982). Moreover, the noun-noun-verb (NNV) frame could represent both the SOV and OSV orders in Turkish. These crosslinguistic differences reflect the children's subtle awareness of different properties of their ambient language. Chan, Lieven, and Tomasello (2009) showed similar results with English-, German-, and Cantonese-learning

children at 2;6, 3;6, and 4;6 years of age in an act-out study. They manipulated the redundancy and conflict of animacy and word order cues in transitive constructions with novel verbs. When the cues were used in coalition, all children succeeded. When the agent and the patient were marked with word order only, English-learning children displayed the earliest comprehension (2;6), followed respectively by German- (towards age 3) and Cantonese-learning (3;6) children. When the animacy and word order cues were presented in a conflicting way (i.e., the first noun in the sentence was inanimate), none of the 2-year-olds showed a systematic preference for the first noun phrase as the agent, whereas children at older ages preferred word order over animacy. These findings indicate that word order is a cue to argument structure in all three languages but that children's sensitivity to this cue is a function of its informativeness in the specific language being learned. Although all three languages have SVO as the canonical word order, German and Cantonese allow more flexible orders, making word order a less available cue for argument structure than in English. Word order cue is even less available in Cantonese compared to German since, like Turkish, Cantonese allows frequent argument noun ellipsis.

Online studies of language comprehension support these offline findings with respect to the overall validity of cues changing across languages. Brouwer and colleagues recently found with a visual world eye-tracking paradigm that Turkish-speaking and Dutch-speaking 4- and 5-year-old children and adults exhibited differences in their linguistic prediction ability (Brouwer, Özkan, & Küntay, 2019). In this task, participants heard SVO sentences with either a semantically constraining verb (e.g., "the boy eats the big cake") or a semantically neutral verb (e.g., "the boy sees the big cake") while they viewed a visual scene composed of a target object (e.g., "cake") and a distractor object (e.g., "tree"). For successful linguistic prediction, participants were expected to utilize verb semantics and word order cues and to direct significantly more looks to the target object "cake" in the semantic condition compared to the neutral condition before they heard the noun *cake*. While both Dutch adults and children demonstrated the prediction effect, this effect was stronger for Dutch adults compared to Dutch children. For Turkish participants, however, only the adult group exhibited the prediction effect. In agreement with a usage-based approach (Bybee, 1985, 1995; Langacker, 1988; Tomasello, 2000), the difference in the prediction effect between Dutch adult and child participants indicates that stronger connections are established between the verb and its arguments in Dutch SVO structures with accumulated language experience, paralleled by more efficient linguistic prediction ability for Dutch adults compared to Dutch children. The lack of a similar developmental pattern for Turkish participants implies that word order might not be as valid of a cue for Turkish-speaking children compared to their Dutch-speaking peers for online processing of argument structure. It may be the case that Turkish children base their online comprehension strategies more on case markers, which were not manipulated in this study, than on word order because case markers in Turkish have relatively high overall cue validity (Göksun, Küntay, & Naigles, 2008; MacWhinney et al., 1991). Additionally, Turkish children may have utilized the semantic information of the verb for the anticipation of the upcoming object less than their Dutch peers did because Turkish allows frequent noun ellipsis. Given the possibility that the object may not follow the verb (i.e., may be dropped), Turkish children may have chosen not to exhaust their processing resources by predicting it. Similar to Dutch adults, the prediction effect observed for Turkish adults could be explained by a usage-based approach.

Findings from English, Turkish, German, and Cantonese indicate that children learning languages with diverse typological properties appear to employ language-specific strategies for learning argument structure, at least in terms of gauging cue validity. This information is gleaned from the input in the ambient language with early sensitivities emerging as young as 12 months of age (Candan et al., 2012). As Dittmar and colleagues (2008) showed, German children at age 2

were able to identify agents and patients in causative structures only when case markers and word order cues redundantly supported each other (i.e., were used in coalition), while at age 5 children became able to use word order by itself, but not yet case markers. Only at age 7 did German children display a preference for case markers over word order when these two cues conflicted, indicating that identifying a cue and gauging its relative validity for argument structure is a developmental process that is closely related to the accumulation of language-specific information extracted from the input. As such, the mastery of utilization of some cues develops at quite late ages as a function of input properties of the ambient language. For German case markers, which exhibit many-to-many mappings of form and function, Dittmar and colleagues (2008) argue that some level of language experience is required for cue reliability to reach a point that German-speaking children can dependably rely on them for interpretations about argument structure.

As opposed to German children, Turkish children exhibit early use of case marker cues in identifying the argument roles of referents in the sentence. Özge and colleagues showed with Turkish-speaking 4- to 5-year-old children and adults in a visual world eye-tracking paradigm that both children and adults could utilize case markers to assign argument structure roles to noun phrases (Özge, Küntay & Snedeker, 2019). Despite their tendency to interpret the first noun in the sentence as the agent, children in this study successfully anticipated the upcoming noun and directed anticipatory looks to its referent in the visual scene. Moreover, children exhibited this pattern of gaze behavior with both canonical and non-canonical structures (i.e., SOV and SVO word orders), in contrast to German-learning 5-year-olds in Dittmar et al. (2008), for whom word order cues were more accessible than case marker cues. Moreover, Turkish-learning children's ability to process and anticipate argument structure in verb-final SOV sentences indicates that case markers in Turkish are utilized for assigning argument structure roles independently of verb semantics as early as 4 years of age. Further, children's ability to process and anticipate argument structure in verb-medial SVO sentences indicates that case markers in Turkish are utilized for argument structure interpretation in non-canonical structures as well. This finding implies that Turkish-learning children may prefer case markers over word order as a cue for argument structure earlier than German-learning children do when these cues conflicted, due to the overall high validity of Turkish case marker cues (MacWhinney et al., 2001). Further studies are required to confirm this prediction.

Other research from morphologically rich languages reveals that verbal morphology can also provide cues to argument structure due to its clarifying function for verb semantics. For instance, the applicative voice (a grammatical voice that introduces oblique objects to the argument structure) in Bantu languages like Sesotho makes the verb's ditransitive interpretation transparent. When the applicative voice marker *-el* is added to the Sesotho verb *pheh-a* "to cook", the verb becomes *pheh-el-a* "to cook for" (Demuth et al., 2003).

| | | | |
|---|---|---|---|
| 1 | Bana | ba-pheh-a | nama |
| | children | AGR-cook-FV | meat |
| | "The children are cooking meat" | | |
| 2 | Bana | ba-pheh-el-a | mme nama |
| | children | AGR-cook-APL-FV[1] | mother meat |
| | "The children are cooking meat for my mother" | | |
| | (*Mme* "mother" is the benefactive; *nama* "meat" is the theme.) | | |

Furthermore, animate objects are required to immediately follow verbs in Sesotho, regardless of the thematic role. For instance, if the theme is animate and the benefactive is inanimate, the theme object must be placed in the immediate postverbal position. If, however, both the

theme and the benefactive objects are of the same animacy, their order is not restricted. Demuth and colleagues (2003) investigated these word order constraints in double object applicative constructions of 3- to 8-year-old Sesotho-speaking children with a forced choice elicited production task. They showed 4-year-olds exhibited an above chance achievement of placing the animate object, rather than the inanimate benefactive, in the immediately postverbal position, indicating early sensitivity to Sesotho word order constraints for double object constructions. Nevertheless, 8-year-olds were still erratic in their performance in this task. Despite their semantic transparency, the protracted development of Sesotho double object constructions reflected their low frequency in child-adult spontaneous speech, hence the low cue availability of the applicative voice. More interestingly, the performance of Sesotho-learning children at age 3 was worse with verbs that frequently occurred in other structures than in double object constructions, suggesting that the infrequent appearance of a verb within a syntactic frame reduces its availability for the learner even though the verb itself is frequently available. This also represents a case of conflict validity, where the transitive meaning of the frequent verbs conflicts with the ditransitive meaning introduced by the applicative voice. Since conflict validity is proposed as an explanation for late development and fine-tuning of some aspects of the language being acquired (Bates & MacWhinney, 1989), the conflict between the transitive meaning of the frequent verbs and the ditransitive meaning introduced by the applicative voice also helps in explaining the late development of applicative voice in Sesotho.

Mayan and Inuit languages provide further intriguing insights for cues to argument structure. For instance, the action of "giving", a transfer event that is typically associated with a three-argument frame in the world's languages, is realized as two different verbs with distinct argument structures (i.e., transitive and ditransitive) in the Mayan language Saliba (Margetts, 2008). Nevertheless, Margetts' naturalistic data shows that children as young as 2;0 exhibited distinct comprehension of these two "giving" verbs. Margetts suggests that the pointing and beckoning gestures that usually accompany adult speech to the child may have helped children learn these verb frames that are frequently used in Saliba child-directed speech (observational data). Inuktitut, an Inuit language, poses another problem for the learning of argument structure. Like Turkish, Inuktitut is characterized by frequent ellipsis such that arguments are omitted as long as the referent can be identified from the discourse or linguistic context. Allen's (2008) studies of children learning Inuktitut, Korean, and Italian reveal children's sensitivity to discourse-pragmatic factors associated with argument informativeness, showing that children learning languages with frequent argument ellipsis utilize pragmatic cues to identify the missing arguments in utterances. The ellipsis phenomena observed in many languages raise the possibility that context-based pragmatic knowledge could be another cue to argument structure in these languages. Notwithstanding the valuable insights and challenges provided by Bantu, Mayan, and Inuit languages for our current understanding of argument structure and the learning mechanisms that are presumably associated with it, most data coming from these languages are limited to naturalistic observations. Conducting experimental investigations in these languages is an urgent requirement for crosslinguistic research, as the number of speakers is quite low.

Japanese is another language that is characterized by frequent ellipsis. Additionally, Japanese case markers (e.g., the subject marker *-ga* and the object marker *-o*) are frequently omitted in both child-directed speech and in the productions of Japanese-learning children until age 5 (Rispoli, 1989; Tanaka & Shirai, 2014). These circumstances pose a serious challenge for Japanese-learning children's acquisition of verb argument structure. In other words, although the cue reliability of Japanese case markers is high, their cue validity is low (Tanaka & Shirai, 2014). Nevertheless, Rispoli (1987) showed that Japanese-learning 2-year-old children made use of verb semantics (e.g., intentionality of the actions) and the animacy cues of theme arguments to learn

transitive and intransitive verb classes despite the flexible word order, optional case marking, and frequent ellipsis that characterized Japanese child-directed speech (Rispoli, 1989). Tanaka and Shirai (2014) further showed that Japanese-learning children benefited from the coalition of animacy and canonical word order cues to learn the verb argument structure from ages 3 to 5. Specifically, they found that the sentences where two arguments were present followed the canonical word order and had the animacy contrast (i.e., one of the arguments was animate while the other was inanimate) simultaneously. This pattern held both for the child-directed speech and for the children's own productions although the frequency of these two-argument structures was extremely low. Tanaka and Shirai concluded that animacy was the strongest cue to argument structure in Japanese, which was followed by word order. Case markers, on the other hand, were used by the mothers when there was no animacy contrast in two-argument structures. These findings from Japanese indicate that cues such as verb semantics, animacy, and word order could be utilized to learn the argument structure of the verb in languages with frequent ellipsis and in languages with case marker omissions. Although animacy might be considered as a universal cue, the specific ways in which it is utilized (e.g., cue coalitions) and its cue validity appear to be subject to crosslinguistic differences.

We have provided evidence from a broad range of languages showing that learning argument structure is a phenomenon that could hardly be explained with a language learning mechanism primarily based on research in English. Children learning different languages arguably need to utilize specific arrays of cues to argument structure, including word order, nominal case markers, verb (e.g., aspect) markers, pragmatics, verb semantics, animacy, and even gestures accompanying child-directed speech. These cues to comprehending and processing argument structure are possibly weighted and activated sequentially or in some instances simultaneously (e.g., cue coalitions) in accordance with the child's developmental stage, input accumulation, language experience, and linguistic context. It appears that strong arguments for children's language learning mechanisms require caution when the acquisition of simple constructions is concerned. Given the variability in cues and strategies employed by children learning diverse languages, crosslinguistic research should focus on diversity, rather than universality. Slobin's (2001) *typological bootstrapping* approach, proposing that tuning to the typological properties of one's language accrues with experience in solving the problems posed by that language, is a promising framework in this respect, as it allows the language learner to use a combination of language-specific cues and strategies to deal with the "puzzles" of the input language. Bates and MacWhinney's (1989) Competition Model provides a systematic framework to implement such a bootstrapping approach. Since increasing language experience will help the learner in this quest, protracted development is expected in some linguistic constructions that are particularly hard to master, such as the later accessibility of case marker cues for German children compared to word order cues (Dittmar et al., 2008). The typological bootstrapping approach can also explain the relatively early use of some cues to argument structure in typologically different languages, such as the early utilization of case marker cues by Turkish children (Özge, et al., 2019). Relative clauses, as a case for complex language, pose an even more difficult challenge for the language learner than argument structure does. Below, we focus on the crosslinguistic research investigating children's acquisition and processing of these structures in an attempt to show that the case of relative clauses proves to be a productive venue for implementing a diversity-not-universality approach to language learning.

## Learning relative clauses

As exemplars of complex language structures, relative clauses have been studied extensively with different methodologies. Experimental studies investigating children's comprehension

and production of relative clauses have revealed which types of relative clauses are easier to process and acquire. Corpus studies, on the other hand, focused on children's spontaneous productions, and demonstrated how language-specific factors influence the input children receive and the output they produce. The increase in the number of studies in typologically diverse languages and thus the increase in the variation of language characteristics that are studied provide a fertile ground to test various theoretical approaches to relative clause processing.

The majority of the experimental studies focus on the differences between processing of subject and object relative clauses. Subject relatives modify a head noun that functions as the subject of the relative clause (e.g., "*the girl* who bought the last copy of that book"), and object relatives modify the direct object (e.g., "*the book* that the girl bought"). In many head-initial languages, where the head precedes its complements, child and adult speakers comprehend, produce, or process subject relative clauses more efficiently than object relative clauses (e.g., de Villiers, Tager Flusberg, Hakuta, & Cohen, 1979; Frazier & Clifton, 1989; Gordon, Hendrick, & Johnson, 2001). This processing difference is termed the *subject relative clause advantage*. Eye-tracking studies with adults have shown that object relatives are read more slowly than subject relatives in English (Traxler, Morris, & Seely, 2002) and Spanish (Betancort, Carreiras, & Sturt, 2009). Studies with children have found that compared to object relatives, subject relatives were produced more frequently in English spontaneous speech (Diessel & Tomasello, 2000), repeated more accurately in English and German (Diessel & Tomasello, 2005), comprehended more accurately in Hebrew (Friedmann & Novogrodsky, 2004), and produced more easily in Danish (Jensen de López, Sundahl Olsen, & Chondrogianni, 2014).

Some theoretical approaches propose a universal advantage for processing subject relative clauses. The Noun Phrase Accessibility Hierarchy (NPAH) asserts that there is a hierarchy of relativizability of different types of noun phrases (Keenan & Comrie, 1977). According to this hierarchy, subject relatives are the easiest to relativize, followed by direct object relatives, indirect object relatives (e.g., "the dog she gave the toy to"), oblique relatives (e.g., "the dog that the girl played with"), genitive relatives (e.g., | "the dog whose collar is lost"; "the dog whose collar the girl bought"), and objects of comparison relatives (e.g., "the dog that the girl is smaller than"). The NPAH argues that languages that are able to relativize on the lower end of the hierarchy can also relativize on the higher end. In other words, if a language has genitive relatives, then that language also has subject, direct object, indirect object, and oblique relatives.

Studies of the acquisition of English relative clauses have found support for the NPAH (Diessel & Tomasello, 2005), but the accumulated crosslinguistic data have shown that the advantage in processing of subject relative clauses is not found universally and is especially not very frequent among languages with head-final relative clauses (for a review in Chinese, see Chan, Matthews, & Yip, 2011). Child speakers of Basque, an ergative and highly inflected language, pointed to the correct picture more often for object relatives than subject relatives in a picture-sentence matching task (Gutierrez-Mangado, 2011). In an elicited production task, children speaking Quechua, an agglutinative language, did not show a difference between subject and object relatives in a production task (Courtney, 2006). Children speaking Finnish, a highly inflected language with head-initial relative clauses, also did not demonstrate a difference between subject and object relative clauses in comprehension and repetition tasks (Kirjavainen, Kidd, & Lieven, 2016).

There are other theoretical approaches that attribute the difficulty of certain types of relative clauses to different phenomena. The Linear Distance Hypothesis asserts that relative clauses that involve a longer linear distance (i.e., more intervening words) between the gap and the filler (i.e., the head noun of the relative clause) are more difficult to process (Gibson, 1998). Examples 3

and 4 demonstrate the filler and the gap structure in English subject and object relative clauses respectively.

3 The girl$_i$ who *GAPi* feeds the dog
4 The dog$_i$ that the girl feeds *GAPi*

The linear filler-gap distance is longer in object relative clauses than in subject relative clauses in English, which is compatible with the experimental findings that point to a subject relative clause advantage. However, this hypothesis is not compatible with findings in Persian (Rahmany, Marefat, & Kidd, 2011), Korean (Kwon, Lee, Goron, Kluender, & Polinsky, 2010), and Turkish. Turkish is a head-final and morphologically rich language with a relatively flexible word order. Examples 5 and 6 demonstrate a subject and an object relative clause in Turkish.

| | | | | |
|---|---|---|---|---|
| 5 | *GAP$_i$* | *köpeğ-i* | *besle-yen* | *kız$_i$* |
| | *GAP$_i$* | dog-ACC[2] | feed-SRC | girl |
| | "The girl who feeds the dog" | | | |
| 6 | *kız-ın* | *GAP$_i$* | *besle-diğ-i* | *köpek$_i$* |
| | girl-GEN | *GAP$_i$* | feed-NSRC-3SG.POS | dog |
| | "The dog that the girl feeds" | | | |

Unlike English, the linear distance is longer in subject relative clauses compared to object relative clauses in Turkish. Hence, according to the Linear Distance Hypothesis, object relatives should be easier to process for speakers of Turkish. However, experiments conducted with adult and child speakers of Turkish showed that adults read subject relatives faster (Bulut, 2012; Kahraman, 2015), and children produced subject relatives more easily in elicited production tasks (Özge, Marinis, & Zeyrek, 2010; Yumrutaş, 2009) and comprehended subject relatives more accurately (Özge, Marinis, & Zeyrek, 2009).[3] When an adult-modeled speech involved object relative clauses, preschool-aged Turkish-speaking children produced more object relative clauses. However, 47% of these were incorrectly formed such that children either omitted the genitive marker on the subject or used the relativizer suffix marking subject relative clauses instead of the suffix marking object relative clauses (Uzundag & Küntay, 2018b). It seems that the morphological complexity of different relative clause structures may be an important factor for children's order of acquisition in highly inflected languages.

As we mentioned previously, speakers of morphologically rich languages can rely on case marking more than word order to make sense of the argument structure (Slobin & Bever, 1982). However, in languages with relatively little inflectional morphology, such as English, word order is a more informative cue to assign thematic roles. From this point of view, the canonical word order hypothesis, which asserts that children should have less difficulty with language structures that have the canonical word order of their language (Bever, 1970), can account for the advantage in processing subject relative clauses in English since these have the canonical SVO word order, as opposed to the object relative clauses that have the OSV order. However, the canonical word order hypothesis fails to explain the lack of such an advantage in Finnish, where subject relatives have the canonical SVO word order, and object relatives have the OSV order. Furthermore, in head-final languages like Korean, Basque, and Turkish, neither subject nor object relative clauses follow the canonical word order. Hence, it is not clear what the hypothesis would predict for these languages. If we assume that it predicts a similar difficulty for subject and object relative clauses, then this prediction is not supported by the data (e.g., Gutierrez-Mangado, 2011; Kwon et al., 2010; Özge et al., 2009, 2010).

The lack of explanatory power of theoretical approaches that measure the complexity of relative clauses without considering their semantic content and frequency in speech is evident in experimental studies that manipulated the animacy of the head noun and participants' exposure to different relative clause types through priming. Frequency effects were found in Wells et al.'s study (2009), where reading speed was increased for object relative clauses after receiving relative clause experience by reading. The effects of semantic content on the processing of relative clauses have been demonstrated for both children and adults. In various languages, object relative clauses with inanimate head nouns are processed more easily than object relatives with animate head nouns (Arnon, 2010; Kidd, Brandt, Lieven, & Tomasello, 2007; Mak, Vonk, & Schriefers, 2002; Traxler et al., 2002). One of the reasons for these findings is that object relative clauses predominantly occur with inanimate heads and personal pronominal subjects (e.g., *the book I bought*) in adult and child speech and/or written corpora as shown in English, German, and Hebrew (Arnon, 2010; Fox & Thompson, 1990; Kidd et al., 2007; Reali & Christiansen, 2007). In an ongoing corpus study in Turkish, we found that children associated subject relative clauses with animate head nouns (94%), and object relative clauses with inanimate entities (100%), at the age when they just started producing relative clauses (Uzundag & Küntay, 2018a). In later preschool ages, however, the proportion of inanimate heads in subject relative clauses increased (57%) to resemble the distribution in child-directed speech (52%). Object relative clauses, on the other hand, were almost always used with inanimate head nouns in both child and child-directed speech (>94%). A strong relationship between subject relatives and animate head nouns was also observed for L2 learners of Japanese (Ozeki & Shirai, 2007a). These findings show that children/second language learners are sensitive to the frequencies of different relative clause configurations in adult speech.

Studies investigating children's acquisition of relative clauses via examining children's and their caregivers' spontaneous speech often use input frequency as a predictor for children's use and order of acquisition of different types of relative clauses. In diverse languages such as Finnish, Japanese, Hebrew, Mandarin Chinese, and Turkish, the frequency distribution of subject, object, and oblique relatives are highly similar across child and caregiver speech, indicating further the important role of input in children's productions (Arnon, 2010; Chen & Shirai, 2015; Kirjavainen et al., 2016; Ozeki & Shirai, 2007b; Uzundag & Küntay, 2018a). Input frequency is also one of the building blocks of a more integrative approach to the acquisition of relative clauses, namely, the usage-based account of language acquisition (Tomasello, 2003). According to the usage-based perspective, the frequency of structures in the input matters, but frequency is not the sole determining factor of children's comprehension and production performance. Linguistic representations are constructed based on experience, where already acquired forms form the basis for later constructions. Hence, the degree of similarity of complex language structures to the constructions that are already in the child's repertoire is important for their acquisition (e.g., Abbot-Smith & Behrens, 2006). In this regard, some relative clauses can be acquired earlier if they are similar to simple sentences in terms of grammatical structure. For instance, in spontaneous speech, English-speaking children produce more subject relative clauses despite hearing object relative clauses more frequently from their caregivers (Diessel & Tomasello, 2000). One of the reasons that subject relative clauses are easier to produce for English-speaking children may be that they are structurally very similar to simple sentences that these children can already produce (e.g., *simple sentence:* "the fish swims", *subject relative clause:* "the fish that swims"). Similarly, child speakers of Mandarin Chinese produce object relatives, which are frequent in the child-directed speech and similar to simple sentences in terms of word order, earlier and more frequently than subject relatives (Chen & Shirai, 2015).

The usage-based account further predicts that simple constructions will be acquired earlier than more complex structures. Findings from several languages lend support for this prediction. English-speaking children's early relative clauses mostly convey a single proposition (e.g., "this is the sugar that goes in there") and act like an extension of the simple clause structure (Diessel & Tomasello, 2000). Similarly, early relative clauses in the speech of child learners of Mandarin are mostly not attached to a matrix verb (Chen & Shirai, 2015). As English- and Mandarin-speaking children grew older, they started to produce more complex structures by attaching relative clauses to matrix clauses that had a non-copular verb, and thus conveying two propositions. In Turkish, we also observed that preschool-aged children's relative clauses were simpler than the relative clauses found in child-directed speech. Children mostly conveyed a single proposition (e.g., "ormanda yaşayan bir ördek *var*", "there is a duck that lives in the forest"), and used early acquired and highly frequent verbs (e.g., *ol-* "be", *yap-* "do") within relative clauses (Uzundag & Küntay, 2018a).

In sum, the usage-based account of language acquisition seems to be an appropriate explanatory framework for the acquisition of relative clauses in diverse languages. Theoretical accounts that specify the complexity of relative clauses on syntactic measures alone cannot explain the experimental findings that the semantic content of the relative clauses and the frequency in the input affect children's comprehension and production processes. Furthermore, language characteristics such as morphological richness and a relatively strict word order also seem to affect the developmental trajectory children demonstrate when acquiring relative clauses. Based on this summary of the literature, we suggest that a successful theoretical approach should take both language-specific and input-specific factors into account.

## Summary

Evidence from crosslinguistic research indicates that research based on English falls short of explaining children's learning of simple (i.e., argument structure) and complex (i.e., relative clauses) structures in various languages. Here, we summarize the common points based on these two linguistic fields of inquiry. Children learning typologically different languages necessarily utilize different arrays and weightings of cues and strategies to learn simple and complex language, and this utilization is bound by the characteristics of the child-directed language input. Protracted language experience may be needed to deal with more complex linguistic tasks (e.g., linguistic prediction) and with more complex linguistic structures (e.g., object relative clauses in some languages). Also, children may need to resolve conflicting cues (e.g., the transitive meaning of frequent verbs vs. the applicative voice in Sesotho) before they can achieve mastery of some linguistic forms, which will presumably result in late or U-shaped development (Bates & MacWhinney, 1989). Thus, extended development for some linguistic forms could, at least partly, ensue from insufficient language experience at a particular point in language development. This means that as children become better language users and better processors with accumulating input, they handle linguistic complexity more efficiently. Protracted development in learning certain linguistic structures is thus a natural process, not a typological or developmental peculiarity. A further point to note is the presumptive reliance of complex linguistic structures on simple ones, such that at least some complex linguistic structures appear to be acquired earlier or more easily than others when they resemble simple sentences. Although recent research implies that cues to argument structure (such as case markers and word order) are more likely to be used for the interpretation of simple structures than complex ones (e.g., simple transitives vs. transitive relative clauses in German; Brandt et al., 2016), future research with typologically

diverse languages may consider the possibility of such dependencies in evaluating how argument structure cues could be translated into learning and processing relative clauses.

## Conclusions

Each language appears to present its own set of puzzles for the language learner. Research on the acquisition of argument structure and relative clauses in diverse languages highlights that advocating a language learning mechanism based only on the typological properties of frequently investigated languages such as English has not proved to be fruitful. One reason for this is that diverse languages have different arrangements of argument slots devoted to the same event (e.g., the transitive "giving" verb in Saliba), different weights associated with the same cues to linguistic structures (e.g., dissimilar cue validity associated with word order), and different semantic and syntactic strategies for marking the event participants and processing complex linguistic structures (e.g., animacy and morphological markers). Thus, diverse languages utilize diverse form-function mappings to signal meaning, and the availability, consistency, and complexity of these form-function mappings differ across languages. The task of the language learner, then, is to glean these form-function mappings from the ambient language input as quickly and as correctly as possible while fine-tuning the language acquired with accumulating experience to achieve optimal communication (Bates & MacWhinney, 1989). As such, usage-based accounts of language learning (Tomasello, 2000), constructionist theories (Goldberg, 2003), and the Competition Model (Bates & MacWhinney, 1989) seem to provide promising frameworks to evaluate and cultivate crosslinguistic research. Slobin's (2001) *typological bootstrapping* approach, which asserts that children become tuned to the typological properties of their language with increasing experience in their language, complements these frameworks and steers crosslinguistic research in the direction of a focus on diversity rather than universality. Future crosslinguistic research should not only investigate linguistic phenomena in the under-studied languages of the world, but also examine language learning by bilingual children who are acquiring typologically distinct languages.

## Notes

1 The following abbreviations are used in glossing the examples: AGR: subject-verb agreement, APL: applicative voice marker, FV: final vowel (mood).
2 The following abbreviations are used in glossing the examples: ACC: accusative, GEN: genitive, NSRC: non-subject relative clause marker, POS: possessive, SG: singular, SRC: subject relative clause marker.
3 The gap precedes the filler in head-final languages, whereas the filler comes first in head-initial languages. For Turkish speakers, Kahraman, Sato, Ono, and Sakai (2010) have shown that as soon as the gap is determined, a gap-filler dependency is constructed. In other words, speakers make use of incremental processing and do not wait until the end of the sentence for analysis.

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# 16

# LANGUAGE DEVELOPMENT IN SIMULTANEOUS BILINGUALS

## The early years

*Fred Genesee*

Many children grow up learning more than one language. This can happen in many ways, for example living in families where parents or other family members speak different languages; living in communities where more than one language is used on a day-to-day basis; attending daycare, preschool, or school programs in a non-native language; and others. Researchers commonly distinguish between simultaneous acquisition of more than one language and successive acquisition of a second or additional language. Although there is no specific and generally agreed upon age for distinguishing between simultaneous and successive dual language learning in childhood, Pierce, Chen, Delcenserie, Genesee, and Klein (2015) provide fMRI evidence that there is a shift in how languages are learned by the end of the first year of life, or earlier (see also De Houwer, 1995, for arguments for a similar cut-off). Even among children who begin learning two languages within the narrow range of birth to 1 year of age, there can be considerable heterogeneity because simultaneous bilingual children are affected by all the factors that can affect monolingual acquisition as well as factors specific to learning more than one language, such as: differences in the amount, consistency, and contexts of language exposure; typological similarity of the languages; and differences in learners' relative proficiency in each language. Moreover, simultaneous bilingual children grow up in different socio-cultural-political contexts where the status, prevalence, utility, and functions of their languages can differ. In this chapter, studies conducted in different socio-cultural settings are considered, and the consistency in their results contributes reliability and confidence to our understanding of simultaneous bilingualism. However, there are few studies that make direct comparisons of language learning in young simultaneous bilinguals in different socio-cultural settings using comparable methodologies. As a result, the extent to which socio-cultural differences influence actual acquisition patterns is an open question, and more cross-cultural research is clearly called for to expand our understanding of this important factor.

There are theoretical and empirical reasons for distinguishing between simultaneous and successive forms of bilingual acquisition. Theoretically, when acquisition of two languages begins at birth, the neuro-cognitive state or maturational level of the brain is the same for both (all) languages being learned, although, arguably, language experiences prior to birth could differentially affect the brain's processing of each language. As a result, the processes, rates, and outcomes of learning in this case might be the same for both (or all) languages, provided learners have adequate exposure to both. In contrast, when an additional language is acquired after 1 year of

age or later, the maturational state of the brain is different for acquiring the first and the additional language (see Pierce et al., 2015, for evidence of this). Moreover, in this case, the learner has already gone through some critical milestones in the acquisition of one language, and this might influence acquisition of the second language. Indeed, there are documented differences in learning processes, rates, and outcomes in successive versus simultaneous bilinguals (e.g., De Houwer, 2011; Dupoux, Peperkamp, & Sebastián-Gallés, 2010; Meisel, 2011; Ortiz-Mantilla, Choudhury, Alvarez, & Benasich, 2010). Finally, the language experiences of simultaneous versus successive bilingual learners are likely to be quite different for the simple reason that people are likely to interact quite differently with neonates and infants than older children, and this could result in different developmental trajectories. The majority of research on children who acquire more than one language at birth has focused on children learning two languages, not multiple languages, and on children acquiring oral languages and not oral and signed languages. Thus, the focus of this chapter is on children learning two oral languages from birth.

Examining bilingual learners during these early formative years is important because it reveals their capacity for learning more than one language during a period of development when language learning is arguably neuro-cognitively optimal because brain maturation is most plastic and learning is not guided by formal instruction as during schooling. This is critical for developing a theory of language learning that goes beyond the monolingual case. Evidence-based insights about neonates' and infants' capacity for the acquisition of two languages can, in turn, shape caregivers' and others' expectations. For example, empirical information is important to inform decisions about: how much and when parents in bilingual homes should or could use more than one language; whether codeswitching by young simultaneous bilinguals is a cause for concern or not; what typical development in simultaneous bilinguals looks like and what are signs of atypical development; and others. Research on young simultaneous bilinguals is also critical for early childcare and school administrators and policy-makers to ensure that they establish and implement developmentally and culturally appropriate policies and practices. Without findings from rigorous research that meet scientific standards, policy-makers, educational administrators, and educators risk making decisions guided by overly simplistic notions of early bilingual acquisition (see Genesee, 2015, for a discussion of myths concerning early bilingual acquisition).

Researchers have often compared the development of simultaneous bilinguals to that of monolingual children. On the one hand, this may be inappropriate because it risks attributing differences between simultaneous bilinguals and monolinguals as deficits in children's capacity to acquire more than one language rather than simply as different types of language learning. The linguistic competencies of simultaneous bilinguals should be examined and understood on their own merit (see also Grosjean, 1997). On the other hand, clinicians, educators, other professionals, and parents often compare young simultaneous bilinguals to monolinguals and make important decisions about how to care for these children based on such comparisons. In other words, comparisons between simultaneous bilinguals and monolinguals have real world consequences. Scientific comparisons between young bilingual and monolingual children can reveal the extent to which learning more than one language during early childhood actually differs from monolingual acquisition and, most importantly, what such differences mean. Indeed, the prevailing perspective is that simultaneous bilingualism is as normal as monolingual acquisition and that there are important similarities and differences between simultaneous bilinguals and monolinguals that should be understood in relation to the contexts in which simultaneous bilinguals acquire their languages (e.g., Pierce et al., 2015).

In the following sections, we begin by examining neonates' and infants' capacity for learning more than one language from birth by reviewing research on the emergence of language

and early word learning. This is followed by a discussion of early vocabulary and grammatical development, and finally communicative competence.

## Getting started

New research methods have made it possible to study language acquisition even before children babble or produce their first words. The first days and months of life (and even prior to birth) are critical for beginning the process of language acquisition. An array of innovative techniques, including non-nutritive sucking methods, head turn preference procedures, and eye-tracking technology, among others, have allowed researchers to detect what children are attending to among the vast sea of sounds they are exposed to at birth (see Byers-Heinlein, 2015; Werker et al., 1998, for more discussion of these methods). These methods examine young learners' ability to focus on language, to discriminate between languages in the environment, to detect and remember speech sounds that are essential for building language, to attach meaning to words, and to begin acquiring the grammar of language. Evidence of these abilities during the first months and year of life is important because it tells us what capacities children are born with that help them get started in acquiring language.

Starting with infants exposed to only one language, this line of inquiry indicates that, within 24 hours of birth, newborns prefer to listen to their mother's voice more than another woman's voice (e.g., DeCasper & Fifer, 1980) or even the father's voice. Infants show that they prefer their mother's voice by visually fixating longer on an image (like a bull's-eye) that has the mother's voice coming from it than an image with an unfamiliar woman's voice. That neonates show such preferences so early after birth is attributable to the fact that prenatal infants are capable of detecting the prosodic qualities of the mother's language while in the womb. Indeed, it has been shown that even babies in utero prefer to listen to the language spoken by the mother over an unfamiliar language (Moon, Cooper, & Fifer, 1993). Additional evidence that newborns have an early start learning language comes from research by Byers-Heinlein, Burns, and Werker (2010), who found that, at 1 to 5 days of age, neonates exposed to English showed a preference for English. Of interest in this chapter, infants exposed to English and Tagalog showed equal preference for English and Tagalog. They also found that the infants who had been exposed to two languages could discriminate between English and Tagalog, ruling out the possibility that they did not show a difference in preference between English and Tagalog because they could not discriminate between the two languages.

Research on the post-natal speech perception abilities of infants has shown that newborn monolingual infants can also differentiate between their native language and a "foreign language" shortly after birth if the languages belong to different rhythmic groups (e.g., such as English and Tagalog; Mehler et al., 1988), and they can differentiate between languages within the same rhythmic group (e.g., Spanish and Catalan) by 4.5 months of age (Bosch & Sebastián-Gallés, 2001; see Polka, Rvachew, & Mattock, 2007, for a review). Bosch and Sebastián-Gallés (2001) found that infants exposed to both Spanish and Catalan were able to differentiate between these two languages at 4 months of age, like their monolingual peers (Bosch & Sebastián-Gallés, 1997; see also Sebastián-Gallés, 2010, for a review of these studies). The ability to focus on and distinguish between specific languages early in development is an important starting point for building separate linguistic systems. Sensitivity to the prosodic aspects of language is also important for acquiring syntactic (word order) features of language. Gervain and Werker (2013) found that 7-month old infants who were learning two languages with different word orders were able to exploit the prosodic differences in the two languages to segment noun phrases from continuous speech. Thus, although these infants had the complex task of identifying the grammatical order

of phrases in two different languages, they were able to exploit correlations in prosody, which is acquired early, and word order to begin to construct the grammars of their two languages.

Additional evidence that newborns are prepared for the acquisition of two languages comes from research on infants' perception of the sounds that make up human language, for example, /b/, /d/, and /u/ in English. Languages differ in their phonemic categories – that is, the sounds that carry meaning in individual words. For example, the sounds /l/ and /r/ are phonemic in English, but not in Japanese. Thus, the words "lot" and "rot" sound different to English speakers and have different meanings. These sounds are not phonemic in Japanese, and, as a result, Japanese speakers do not hear differences in nor do they attribute different meanings to words in Japanese that include these sounds. As well, the English words "lot" and "rot" would sound the same to many monolingual Japanese speakers. Infants begin life with the ability to discriminate many consonant and vowel sounds in the world's languages, regardless of their experience with specific languages. This is an important ability for young simultaneous bilinguals because it means that they have the capacity to discriminate many of the sound segments they need to construct two languages, prior to extensive experience with those languages. Experience does matter, however. Monolingual infants' ability to discriminate speech sounds becomes language-specific during the second half of the first year of life so that they continue to discriminate phonetic contrasts that are phonemic in their native language after this age, but cannot discriminate or have difficulty discriminating contrasts that are not phonemic (Bosch & Sebastián-Gallés, 2003; Kuhl, Williams, Lacerda, Stevens, & Lindblom, 1992; Werker & Tees, 1984). Researchers in Spain, Canada, and Wales have found that simultaneous bilingual infants go through a similar reorganization in speech perception at roughly the same ages as their monolingual peers (Albardea-Castellot, Pons, & Sebastián-Gallés, 2011; Burns, Yoshida, Hill, & Werker, 2007; Sundara, Polka, & Molnar, 2008; Vihman, Thierry, Lum, Keren-Portnoy, & Martin, 2007).

However, there may be phonemic contrasts that infants exposed to two languages take longer to discriminate. For example, Sebastián-Gallés and Bosch (2002) found that infants exposed to both Spanish and Catalan could discriminate a contrast that exists in Catalan but not Spanish only at 12 months of age, whereas infants exposed only to Catalan were able to detect the contrast at 8 months. The authors argued that the Spanish-Catalan infants treated the contrasting phonemes in Catalan as a single category because they belonged to a single category in Spanish. As a result, the bilingual infants required more time to disentangle the distribution of these sounds in Catalan and Spanish. Thus, the perceptual abilities of some infants exposed to two languages may differ from those of infants with monolingual exposure with respect to specific phonemic contrasts because of the complex phonetic properties of their two languages and not because of perceptual limitations per se. In a related vein, Garcia-Sierra et al. (2011) found that 6–9-month old infants exposed to Spanish and English in the U.S. did not show neural discrimination of contrasts in Spanish or English, while monolinguals did. These authors argued (p. 555) that "[a]daptively, bilingual infants could remain more 'open' – that is, less neutrally committed" – than monolinguals given the greater variability in language input they are exposed to. Adaptability among simultaneous bilinguals is illustrated further in a study by Weikum and colleagues, who found that while both 4- and 6-month old monolingual and bilingual infants attended to and discerned differences in facial movements associated with different languages, 8-month old monolingual infants failed to do so whereas the simultaneous bilingual infants continued to notice facial cues that differentiated French and English (Weikum et al., 2007). This is a useful strategy for simultaneous bilinguals because they need to distinguish between two languages, whereas monolinguals do not (Pons, Bosch, & Lewkowicz, 2015). Using additional cues in these ways, be it prosodic differences between languages to discern grammatical categories or facial movement to discriminate languages, is a strategy that allows young infants exposed to two

languages from birth "to separately track and learn about the properties of each of their two languages" (Werker, 2012, p. 6). Monolingual infants are less likely to exploit these additional cues as much because they do not need to.

In brief, extant evidence indicates that learning aspects of language that are critical for language learning right after birth is no more challenging for neonates exposed to two languages than for neonates exposed to one. This is evidenced in both the early listening preferences and the perceptual fine-tuning that simultaneous bilinguals exhibit at birth and by the end of the first year of life, respectively. At the same time, complex and subtle phonetic differences in their developing languages can slow down this essential fine-tuning process; similar effects have been found in other areas of development and will be considered later. Differences between neonates exposed to two languages versus one suggest flexibility in the processes simultaneous bilinguals engage to learn language; this is attested to by evidence that the phonemic boundaries in their two languages may remain open longer than is found among monolinguals; they use facial cues longer than monolinguals, arguably to differentiate between their developing languages; and they use prosodic differences in their developing languages to begin learning the grammars of each.

## Early word learning

Words are also an important foundational element for building language. Word learning is a complex task. It entails segmenting words from the speech stream, knowing the sounds that make up words in the language being learned and the order in which they occur (called phonotactics), attaching meaning to new words, and figuring out the grammatical roles of words. In this section, three different lines of research are reviewed that relate to early word learning: phonotactics, word segmentation and recognition, and associative word learning. At present, research in these domains is relatively limited, and thus evidence is still emerging. Nevertheless, a coherent understanding of these aspects of bilingual acquisition is beginning to emerge, one that emphasizes processes common to monolingual and simultaneous bilingual acquisition and differences that reflect the complexities of learning languages with different phonetic and phonotactic properties at the same time.

Languages differ not only in their phonemic inventories (discussed earlier), but also in the combinations and sequences of sounds that are permissible in the language; for example, consonant clusters exist and are common in English but not Japanese, and clusters like /kn/ and /gn/ are permissible at the beginning of words in German but not English. Research has shown that, around 9 months of age, monolingual infants prefer to listen to pseudo-words that conform to the phonotactic properties of their native language in contrast to pseudo-words that violate those constraints (e.g., Jusczyk, Friederici, Wessels, Svenkerud, & Jusczyk, 1993). Research on infants learning two languages suggests a more complex picture. On the one hand, Vihman et al. (2007) found that the ability of 11-month old infants exposed to both Welsh and English to recognize words that conformed to the phonotactic constraints of their developing languages was similar to that of infants learning each language monolingually. On the other hand, research by Sebastián-Gallés and Bosch (2002) with 10-month old infants exposed to both Spanish and Catalan suggests exposure and language dominance can be influential. They found that, as expected, monolingual Catalan infants preferred listening to words that conformed to Catalan phonotactic constraints in contrast to those that violated those constraints, and Spanish monolinguals showed no preference, as expected, since the contrast they were presented was phonemic in Catalan but not Spanish. The Catalan-dominant bilingual infants also showed a preference for the words that conformed to constraints on Catalan, whereas the Spanish-dominant bilingual

infants showed no preference. These findings indicate that recognition of permissible phonotactic constraints by young simultaneous bilinguals can depend on their relative exposure to each language and that the emergence of a monolingual-like pattern is more likely in the bilingual infant's dominant language. They also suggest that the typological similarity of the two languages may play a role insofar as Welsh and English are phonologically quite different whereas Catalan and Spanish are relatively similar.

There is evidence that it can take time for children to acquire stable and detailed representations of the sounds that make up words and that it can take simultaneous bilinguals even longer because the phonological variations in their two languages are more complex than is the case for monolinguals. Relative proficiency in each language of the bilingual, or what is sometimes called dominance, can also make a difference. Specifically, Ramon-Casas, Swingley, Sebastián-Gallés, and Bosch (2009) used a "looking-while-listening" task in which infants were asked to look at one of two side-by-side pictures in response to a command that included a correct or an incorrect pronunciation of one of the objects (e.g., "look at the fish/fesh"). Monolingual infants typically look longer at the correct object when they are presented with the correctly pronounced label. These researchers presented 18-month old monolingual and bilingual Spanish-Catalan infants with target words that included a difference in pronunciation that was phonemic in Catalan but not in Spanish. The Catalan monolinguals looked more at the correctly pronounced target work, indicating that they perceived the mispronunciation, whereas neither the monolingual Spanish children nor the Spanish-Catalan bilinguals displayed differential looking at the correctly and incorrectly pronounced words. The researchers interpreted these findings as evidence that bilingual learners may take longer to learn phonetic contrasts that are phonemic in one language but not the other. It is also possible that children learning two languages simultaneously get linguistic input from second language speakers of each language and, as a result, are exposed to unstable and/or even mispronounced word forms, a point we return to later. As a result, it could take them longer to establish stable phonological representations of word forms than monolinguals (see also Lieven, 2010; Sebastián-Gallés, 2010). It may also be that children learning two languages keep the phonological boundaries around phonemic categories in their two languages relatively open or permeable in order to accommodate the variable forms they hear, as noted earlier. In effect, the latter possibility represents an adaptive strategy in response to inherently complex and variable input.

The ability to segment words from continuous speech is another important step in language development and, in particular, in early word learning. Because there are no acoustic cues that signal the beginnings and ends of words in continuous speech, segmentation of words in natural speech requires knowledge of the phonotactic properties of familiar word forms. It has been hypothesized that infants learn to segment words in speech by tracking the predictability of syllables within words and across word boundaries (see Chapter 4, this volume, for a detailed discussion of this strategy). Bosch, Figueras, Teixidó, and Ramon-Casas (2013) examined the word segmentation abilities of infants exposed to Spanish and Catalan. All participating children (monolingual and bilingual) were first exposed to and familiarized with orally presented sentences that contained target pseudo-words comprising sounds and sound sequences that were legitimate in Spanish or in Catalan. After the familiarization phase, they were then exposed to orally presented test words, some of which they had heard during the familiarization phase and some of which they had not. All language groups (bilingual and monolingual) could segment the familiar words from continuous speech by 6 months of age although they exhibited more advanced segmentation abilities at 8 months (see also Polka & Sundara, 2003, for similar results from 8-month old French-English bilinguals).

It is believed that associative learning (pairing new words with new events/objects) is one strategy that young children use to acquire the meaning of new words. Indeed, studies of monolingual infants have shown that they can learn new word-object associations by as young as 6 months of age (Friedrich & Friederici, 2011). The question is whether exposure to two languages during infancy alters the time course of this strategy. To test this, Byers-Heinlein, Fennell, and Werker (2013) examined 12- and 14-month old monolingual and bilingual infants on an associative learning task that involved words that differed phonetically in several ways; for example, the novel word /lif/ and the novel word /neem/ differ with respect to their initial, medial, and final sounds. The monolingual participants were from English-speaking families, and the bilingual participants had had exposure to English and another language from birth. The children were tested using the switch task (Werker et al., 1998), in which they were first exposed to novel word-object pairings several times, followed by trials in which some of the word-object pairs were switched. Neither the 12-month old monolinguals nor the bilinguals detected a violation of the previous word-object pairings, but both groups succeeded at 14 months of age. Of importance, there was no difference in the performance of the bilingual and monolingual children at 14 months of age.

Using the switch task, it has also been found that infants who are learning one language can learn associations between novel objects and new words that are composed of minimal pairs at 17 and 20 months of age but not at 14 months of age. This is a more complex task since the novel words differ in only one sound. In contrast, infants learning two languages from birth may have difficulty with this task and do not succeed until 20 months of age (Werker, Fennell, Corcoran, & Stager, 2002; Fennell, Byers-Heinlein, & Werker, 2007). However, follow-up research by Fennell and Byers-Heinlein (2014), as well as research by Mattock, Polka, Rvachew, and Krehm (2010), suggests that success on this demanding task may depend on whether the novel words to be learned match the language environment in which the children are learning language. In conditions when the bilingual children were tested with minimal pairs produced by bilingual speakers, they were able to learn the minimal pairs at 17 months of age, whereas the 17-month old monolingual children could not. Taken together, these studies show that both groups of learners were successful at 17 months of age if the testing conditions matched the language environments (monolingual or bilingual) in which they were learning their languages.

Despite some similarities, word learning by simultaneous bilinguals differs from that of monolingual children. For example, children's acquisition of the meaning of new words is generally thought to be constrained by what is referred to as the "mutual exclusivity" bias. Mutual exclusivity constrains children's word learning so that they associate one label with one object and avoid associating the same object with multiple labels. This has been shown extensively in 17-month old monolingual infants (e.g., Halberda, 2003; Markman & Wachtel, 1988). However, while mutual exclusivity may be a useful heuristic for learning one language, this is not the case for children learning more than one language, where objects usually have more than one label. Indeed, a number of studies of bilingual learners have shown that they are less likely than monolinguals to apply the mutual exclusivity constraint when tested in experimental situations (e.g., Bosch & Ramon-Casas, 2014; Byers-Heinlein & Werker, 2009; Houston-Price, Caloghiris, & Raviglione, 2010). Moreover, analyses of young simultaneous bilinguals' natural language use indicate that they often have translation equivalents – different labels in each language for the same object, event, or quality (e.g., red, big) (Pearson, Fernandez, & Oller, 1993). The prevalence of translation equivalents in bilingual children varies depending on the number of languages they are learning – it is more evident in children learning three languages than in children learning two (Byers-Heinlein & Werker, 2009) and in children learning languages that have numerous cognates, such as Spanish and Catalan (Bosch & Ramon-Casas, 2014). Violation of

the mutual exclusivity bias, extended attention to facial cues, and use of prosody to discriminate languages can be seen as adaptive strategies that simultaneous bilinguals use to unravel and master the complexities of two languages.

In brief, there is a complex pattern of similarities and differences in the early word learning of simultaneous bilingual and monolingual children. On the one hand, similarities are most evident when general strategies and processes of early word learning are examined – perception of the phonotactic properties of input languages, learning of the meanings of new words through associative learning, and segmentation of words from continuous speech. However, differences emerge when detailed analyses of early word learning are examined and when contextual factors are considered. Thus, it has been found that young bilinguals' early word learning can depend on fine-grained differences in the phonetic properties of their input languages, their relative dominance in or exposure to each language, and the quality of the input and, in particular, whether input corresponds with the bilingual environment they have been exposed to. There is still a great deal to learn about this complex and important stage of language learning, a period of development when micro-level differences in language input seem to play an important role.

## Vocabulary development

Of all the components of language, vocabulary is arguably the most susceptible to experiential and contextual factors. As noted earlier, simultaneous bilinguals are subject to the same sources of variation in development as monolingual children as well as unique sources of variation linked to the realities of acquiring two languages. Many of these bilingual-specific sources of variation implicate the quality, quantity, and continuity of the input bilinguals experience in each language, as well as the typological similarities/differences in the languages they are learning, developmental/age-related changes, and variations in the contexts and circumstances in which bilingual children acquire their languages. A common metric of development and the subject of much empirical investigation is the number of words simultaneous bilinguals know in each language; but other metrics include rate of vocabulary development, number of translation equivalents, and speed and accuracy of lexical processing (see Chapter 6 in De Houwer, 2009, for a more comprehensive and detailed discussion of vocabulary development in simultaneous bilinguals than this chapter can offer due to space limitations). The number of words is the focus of attention below since it has received a great deal of empirical attention.

Studies of vocabulary development in simultaneous bilinguals that entail comparisons with monolinguals learning the same languages or with test norms have produced divergent findings. Some report a vocabulary advantage for monolinguals (e.g., Bialystok, Luk, Peets, & Yang, 2010; De Houwer, Bornstein, & Putnick, 2014; Hoff et al., 2012), some an advantage for bilinguals (e.g., Aquila, Ramon-Casas, Pons, & Bosch, 2007; De Houwer et al., 2014; Legacy, Zesiger, Friend, & Poulin-Dubois, 2015), and some no differences (e.g., Hoff, Rumiche, Burridge, Ribot, & Welsh, 2014; Pearson et al., 1993; Poulin-Dubois, Bialystok, Blaye, Polonia, & Yott, 2013; Sundara, Polka, & Genesee, 2006). More detailed examination of these studies reveals that these divergent findings can often be explained by a number of methodological issues, including the language modality that was assessed: comprehension versus production (e.g., De Houwer, 2007), the age of the participants (e.g., Legacy et al., 2015), the specific measure of vocabulary used in the comparison: single versus double language counts (e.g., Pearson et al., 1993), the relative level of proficiency of each child in each language (Pearson et al., 1993), exposure (Legacy et al., 2015; Thordardottir, 2011), and the configuration of parental language use (e.g., Hoff et al., 2014).

That there are methodological differences among these studies does not mean that their findings are not valid; but it indicates that it is difficult to draw general or simple conclusions from

this body of research because studies on this topic are often not comparable. More important perhaps, these findings illustrate that a full understanding of vocabulary development in simultaneous bilinguals requires consideration of the multiple factors that can influence vocabulary acquisition. For example, comparisons between the languages of the same bilinguals reveal that they tend to score significantly higher on vocabulary measures in the language to which they have relatively greater exposure (Pearson et al., 1993), and often as high as or higher than the scores reported for monolinguals. To the extent that children learning two languages talk about different things with different people for different purposes, one would also expect their vocabulary knowledge in each language to also differ from one another and from that of monolinguals learning the same languages (see also Grosjean, 2016). In this regard, Bialystok and colleagues examined the types of English words (home- versus school-related) known by a large group of bilingual and monolingual children (n = 1738) between 3 and 10 years of age, all of whom were being educated in English (Bialystok et al., 2010). The bilingual children spoke a variety of non-English languages at home and were reported by their parents to use both languages on a daily basis and to be fluent in both. The mean total vocabulary score in English of the monolinguals was significantly higher than that of the bilingual participants, although there was considerable overlap in the distribution of the two groups' scores so that many bilinguals achieved the same or higher scores than the monolinguals. When their vocabulary scores were analyzed by context, differences between the monolingual and bilingual participants were evident only when vocabulary related to home-related words was examined. The researchers argued that there were no between-group differences in school-related vocabulary because school had a homogenizing effect on their vocabulary knowledge. Evidently, the vocabulary repertoire each child has in each language depends on who speaks each language to the child and for what purposes.

Relative differences in exposure to each language might also be linked to differences in vocabulary knowledge in each language (e.g., Barnes & Garcia, 2013). Indeed, in the limit, it is to be expected that less exposure in a language will result in reduced knowledge or competence – for example, bilingual children with only 20% exposure to a language would be expected to acquire less knowledge and competence in that language than children with 80% exposure. Precisely how much variation in exposure affects vocabulary knowledge and under what circumstances is open to empirical investigation. In this regard, Thordardottir (2011) examined the vocabulary development of bilingual French-English 5-year olds living in Montreal who had begun learning their second language before 3 years of age. Of note, statistical analysis of early onset bilinguals (before 6 months of age) and late onset bilinguals (20 months of age or older) revealed no significant differences in their vocabulary scores. The performance of the bilingual learners was compared to that of monolingual French- and monolingual English-speaking children. She found that there was a strong relationship between amount of reported exposure to each language and performance on the vocabulary measures. More specifically, and generally speaking, bilinguals with approximately equal exposure to both languages scored comparably to the monolinguals in receptive vocabulary, and exposure beyond that limit did not yield additional growth for the bilinguals; exposure below 40% resulted in scores for the bilinguals that were below those of the monolinguals. More exposure was required for the expressive vocabulary scores of the bilingual children to reach parity with the monolingual children. Thordardottir provides evidence that this may be true for grammar as well, although the threshold level to achieve parity with monolingual norms is higher than in the case of vocabulary. Thus, there may be a threshold level that is necessary to achieve parity with monolingual norms, and threshold levels may differ depending on the domain of language being examined. Thordardottir based her analyses on parental reports of their children's relative exposure to each language. This raises the question of how best to assess exposure.

It is often assumed that, on average, simultaneous bilinguals are exposed to less input in each language than monolinguals, and this has often been used as a basis for expecting simultaneous bilinguals to have smaller vocabularies than monolinguals, which, as we have seen, is often not true. However, even a hypothetical bilingual learner with only 50% exposure to each language could actually receive more input in one or both of those languages than a monolingual child if her or his caregivers were much more attentive and talkative than the monolingual caregivers (De Houwer, 2014). Exposure is often assessed by asking parents to report in percentages how much relative time their children are exposed to each language over some interval of time – for example, 50%/50% or 40%/60% during the preceding weeks or months. Whether this is the most accurate and only measure of exposure that should be examined is open to question. For example, should estimates of exposure be based on relatively short time intervals immediately preceding the study or time intervals that are longer and less recent; should exposure be determined in actual time (i.e., number of minutes or hours per time interval) or in relative terms (as above); or should the actual number of words, phrases, or sentences/utterances used by caregivers with their child for a specified time interval be counted (e.g., De Houwer, 2007; see also Gruter & Paradis, 2014, for research and detailed discussions of this and related issues on input).

Assessing only one language of simultaneous bilinguals or assessing each language separately does not provide a complete picture of their vocabulary knowledge, nor of their capacity for word learning, since it does not take into account all the words they know. In a landmark study of Spanish-English bilingual children (8–30 months of age) in Florida, Pearson et al. (1993) examined the vocabulary of the children using single language and double language scores. The single language scores comprised their separate scores on the English and Spanish versions of the Peabody Picture Vocabulary Test. There were two double language scores. The Total Vocabulary score was a simple combination of their two single language scores. The Total Conceptual Vocabulary score was calculated by giving each child credit for every different word they knew in at least one of their languages; the same words known in both languages were not counted twice. They found no differences between the bilingual and monolingual children when the double language scores of the bilingual children were examined. In fact, they found that the bilinguals scored numerically higher than the monolinguals when both languages were included in the calculation, although these differences were not statistically significant. Pearson and colleagues also found no differences between the bilinguals' scores in their dominant language in comparison to the corresponding monolingual norms (i.e., English only or Spanish only) (see also Hoff et al., 2012). These findings are particularly important because they indicate that the capacity of young learners exposed to two languages to acquire vocabulary is the same or arguably even enhanced in comparison to that of children exposed to one language. These results indicate further that it is imperative to assess the vocabulary knowledge and skills of young bilingual learners in both languages in order to determine their language learning capacity. Limiting assessment to only one language could give the false impression of delayed or even impaired ability (see Paradis, Genesee, & Crago, 2011, for extended discussion of assessment issues when cases of suspected impaired language learning are being considered).

Yet another factor to consider when assessing and trying to understand the vocabulary development of simultaneous bilinguals either in each language or in comparison to monolinguals is age. Deanda, Arias-Trejo, Poulin-Dubois, Zesiger, and Friend (2016) have suggested that the effects of exposure may be more pronounced in younger learners when the lexical system is relatively immature. By implication, and as suggested by the results from Thordardottir, differences might diminish and even disappear with age as bilingual children have more cumulative exposure to each language (see also Paradis, Tremblay, & Crago, 2014).

Taken together, these studies indicate that young simultaneous bilinguals often exhibit the same vocabulary knowledge as monolingual learners, or greater knowledge, and that they demonstrate the same capacity for word learning in two languages as monolingual children. They also indicate that simple conclusions about differences in vocabulary between bilingual and monolingual learners are often problematic and are to be avoided because of methodological differences among studies. A number of factors can influence the vocabulary development of simultaneous bilinguals and should be considered when assessing their vocabulary knowledge. It is particularly important in clinical settings to have a thorough and comprehensive knowledge of these sources of influence on both languages when professionals seek to understand individual bilingual learners in order to determine their need for additional language learning support. Differences that might suggest concerns of a clinical nature may simply reflect the complex array of factors that impinge on bilingual development and may not be attributable to underlying impairment (see Paradis et al., 2011, for more discussion of clinical issues).

## Morphosyntactic development

An early and predominant issue in research on the language development of young simultaneous bilinguals was whether they acquire differentiated grammars and how early in development this is evident (e.g., Volterra & Taeschner, 1978). This hypothesis was linked to the observation that young simultaneous bilinguals use words from both languages in the same utterances and conversations, creating the impression that they cannot differentiate between their two languages. In fact, there is a consensus among researchers that this hypothesis is incorrect and, to the contrary, that young bilinguals acquire separate grammars, for the most part and under most circumstances, from the earliest stages of development. There are multiple sources of evidence for this conclusion. To begin, when young simultaneous bilinguals code-mix (that is, use elements from their two languages in the same utterances), most of the time they do so in ways that respect the grammatical constraints of each language (e.g., Paradis, Nicoladis, & Genesee, 2000; see Genesee, 2002, for a review). In addition, most simultaneous bilinguals in the two-word and multi-word stages of development produce many more single language utterances than mixed utterances (De Houwer, 2009; Genesee, Nicoladis, & Paradis, 1995; Schelletter, Sinka, & Garman, 2001). During dyadic interactions with adult monolinguals or bilinguals who prefer to use only one of their languages, young simultaneous bilinguals use the monolingual interlocutors' only or preferred language more, indicating that they can use their languages differentially and intentionally (Genesee, Boivin, & Nicoladis, 1996).

More direct evidence of differentiated grammars comes from studies of within- versus between-language interdependencies in development. There is evidence of developmental interdependence of different aspects of language within languages but not across languages. Conboy and Thal (2006), for example, found that the rate of change in the use of predicates and closed-class words in English and Spanish among a group of young Spanish-English bilinguals (between 19 and 31 months of age in the U.S.) correlated within but not across languages. They also found that total vocabulary in each language was correlated with use of predicates and closed-class words within languages but not across languages. Similarly, changes in grammatical complexity with age were related to changes in productive vocabulary in each language but not across languages (see also Patterson, 1998). It is also interesting to note here that research on young monolingual children has shown that vocabulary size and growth are related to grammatical complexity, indicating that the same relationships and possibly causal factors underlie grammatical development in both young simultaneous bilingual and monolingual learners.

In principle, young simultaneous bilinguals could acquire separate grammars early in development, but their grammars might develop differently from those of monolinguals. In fact, in-depth studies of the acquisition of specific grammatical structures and constraints indicate that, for the most part, young bilinguals exhibit the same patterns of morphosyntactic development as monolinguals, other things being equal (see De Houwer, 2011; Paradis et al., 2011, for reviews). For example, young Spanish-English bilinguals exhibit language-specific and appropriate use of predicates and closed-class words in English and Spanish (Conboy & Thal, 2006). Paradis and Genesee (1996) found that young French-English bilinguals in Montreal exhibited the same patterns of usage with respect to finite verbs, subject pronouns, and verbal negation, as same-age monolingual French and English learners. These are language-specific grammatical properties, and, thus, the bilingual learners in Paradis and Genesee's study can be said to exhibit both language-specific and language-appropriate usage. Meisel (1986, 1989) similarly found language-specific morphosyntactic development in a longitudinal study of French-German bilinguals in Germany (see Gutierrez-Clellen, Simon-Cereijido, & Wagner, 2008, for evidence from Spanish-English bilinguals in the U.S.).

Evidence that developmental relationships between different aspects of grammar in young simultaneous bilinguals are the same as or similar to those of monolinguals would argue that the same neuro-cognitive processes drive language learning in both groups of learners and that these processes operate modularly in the case of simultaneous bilinguals. Support for this comes from evidence that monolingual children begin to produce two-word combinations only once they have acquired some minimum number of words, usually thought to be about 50 (e.g., Marchman & Bates, 1994); the same link has been found in young simultaneous bilinguals (David & Wei, 2008; Junker & Stockman, 2002). Similarly, young bilinguals, like young monolingual learners, tend to omit function or closed-class words and grammatical morphology during the two-word stage and in some of their three-word and even their multi-word utterances. This means that young bilinguals use primarily content, referential, and/or social words to refer to objects, people, events, and characteristics of their immediate environment during the earliest stages of grammatical development (e.g., *pretty doggy*, *mommy go*), like monolinguals. The relative proportion of different kinds of words changes as children's vocabularies grow; the same shift is noted in simultaneous bilingual and monolingual children (Conboy & Thal, 2006). There is also a correlation between vocabulary size and overall complexity of utterances produced in each of simultaneous bilinguals' languages and in monolingual children (Marchman, Martínez-Sussmann, & Dale, 2004).

Notwithstanding many similarities, there are differences between young simultaneous bilinguals and monolinguals. A number of factors can explain such differences. In cases when the source of input for one or both languages of a bilingual learner is a non-native speaker, then they might actually hear and then produce grammatical forms that deviate from monolingual norms. For example, in a case study, Paradis and Navarro (2003) found that a Spanish-English bilingual child who used more overt subjects in Spanish than is typical of Spanish monolingual children actually heard more overt subjects in the Spanish used by her mother, a second language learner of Spanish (see De Houwer, 2009, pp. 285–286, for synopses of other studies that have found a relationship between adult usage and young bilinguals' productions). Simultaneous bilinguals who speak a minority language and are increasingly exposed to the majority language as they come into more contact with that language as a result of schooling in the majority language and/or contact with native speakers of that languages outside the home often show an increased preference to use the majority language. Under such circumstances, grammatical competence in the minority language can begin to diminish. This could result in deviations in underlying

knowledge and in overt use of specific grammatical structures and constraints in comparison to typical monolingual patterns (Montrul, 2008).

Crosslinguistic influences can also influence the grammatical development of simultaneous bilinguals, resulting in difference in their grammars in comparison to those of monolinguals. Crosslinguistic influences or interactions could result in deviant or simply atypical usage in comparison to monolingual patterns. An example of the latter was reported by Paradis and Navarro (2003), discussed earlier. An example of the former is the substitution of a word order rule from one language when using the other language. Yip and Matthews (2007) documented this effect in the language of 2.5- to 4-year old Cantonese-English children who formed relative clauses in English using the Cantonese pattern; these children were more proficient in Cantonese. Similarly, Döpke (1998) found that some of the young German-English bilingual children she studied in Australia used English word order when speaking German. Nicoladis (2002) found crosslinguistic influence in French-English children's use of compound words (for example, using the French order "brushteeth" (brosse-à-dents) instead of the correct English order "toothbrush"). There is no evidence that crosslinguistic influences are pervasive (i.e., broad in scope) or long lasting, except possibly in the case of children who have limited exposure to a language (see Meisel, 2011; Paradis et al., 2011, for reviews).

Two main explanations have been put forward for crosslinguistic influences of these types. Hulk and Müller (2000) argued that crosslinguistic effects are more likely when the grammatical constraints or properties of the two languages overlap. For example, with respect to the use of sentential subjects, Spanish allows subjects to be null or overt, but English requires overt subjects. The optional use of null subjects in Spanish might "invite" influence from English to Spanish, but the other way around is less likely because English requires sentential subjects. The second explanation entails issues related to language dominance. If children are more proficient in one language than the other, crosslinguistic effects from the dominant to the non-dominant language can occur, as was found in Yip and Matthews' Cantonese-English bilingual children.

Young simultaneous bilinguals, like young monolinguals, vary greatly in their rate of language development; this is true for morphosyntax as it is for vocabulary. Thus, as noted in the section on vocabulary development, comparing the morphosyntactic development of simultaneous bilinguals to that of monolinguals is complex because simultaneous bilinguals are subject to all the individual difference factors that influence development in monolinguals as well as bilingual-specific sources of influence. In particular, linking the amount of exposure to each language with morphosyntactic development in young bilinguals is fraught with the same methodological complications noted earlier for vocabulary development. However, once again, it is probably reasonable to expect that below some minimum level of exposure, simultaneous bilinguals will not achieve the same level of grammatical competence in one of their languages as monolinguals learning the same languages. Indeed, it has been found that there is an association between relative amount of exposure and morphosyntactic development in young bilinguals (e.g., Hoff et al., 2012; Thordardottir, 2011). Also like vocabulary development, the relationship between exposure and outcome is not linear; that is to say, greater exposure to a language beyond some threshold may not consistently produce greater grammatical competence in that language (Thordardottir, 2011).

Notwithstanding these caveats, aggregating across a number of studies, and generally speaking, it is evident that simultaneous bilinguals exhibit the same patterns of morphosyntactic development as monolingual learners. More specifically, when general milestones in grammatical development have been examined, there is no evidence to indicate that simultaneous bilinguals are likely to fall behind norms established for monolingual learners, assuming that

some minimum amount of exposure to each language is available to the learner. This has been found for indices such as mean-length-of-utterance (Paradis & Genesee, 1996), emergence of two-word combinations (around 2 years of age), production of short sentences with some inflectional morphemes (around 30–36 months of age), and production of complex utterances/sentences (around 48 months of age) (see De Houwer, 2009, p. 37, for a summary of language development milestones from birth to age 5). On the one hand, the finding of such robust similarity in the emergence of certain milestones in simultaneous bilingual and monolingual language development would argue for common underlying neuro-cognitive strategies in both cases.

On the other hand, examination of the acquisition of specific aspects of morphosyntax during the preschool years has revealed some differences between simultaneous bilinguals and monolinguals under some circumstances. For example, Nicoladis and colleagues found that French-English bilinguals in Edmonton, Canada, exhibited lower levels of accuracy when using verbs in the past tense in both languages than their monolingual peers at 4 to 6 years of age (Nicoladis, Palmer, & Marentette, 2007). In a follow-up study, Paradis, Nicoladis, and colleagues, however, found that bilingual children could be as accurate as monolinguals at this age in their use of the past tense in their dominant language (Paradis, Nicoladis, Crago, & Genesee, 2011), once again attesting to the importance of examining simultaneous bilinguals in both languages or at least their dominant language. Socio-cultural factors may also play a role. Pérez-Leroux and her colleagues found that 3-year old French-English bilinguals living in Toronto, an English-dominant city, lagged behind monolinguals in their use of object pronouns in French, a notoriously difficult aspect of French morphosyntax (Pérez-Leroux, Pirvulescu, & Roberge, 2009). In contrast, Paradis, Crago, and Genesee (2006) failed to find such a difference in same-age French-English bilinguals and monolinguals in Montreal, a French-dominant city. In a related vein, studies of morphosyntactic development carried out in the U.S. on Spanish-English simultaneous bilinguals in comparison to bilingual learners in Canada also attest to the potential influence of socio-cultural factors on rates of development. Specifically, a number of researchers have reported that simultaneous bilinguals in Miami lag behind their monolingual peers in both languages (Gathercole, 2007; Hoff et al., 2012; Oller & Eilers, 2002); in contrast, this has not always been found for young simultaneous bilinguals in Canada (e.g., Thordardottir, 2011; Paradis & Genesee, 1996).

Complexity may also affect simultaneous bilinguals' acquisition of specific morphosyntactic structures. This is illustrated in a large-scale study of Welsh-English bilingual children in Welsh medium schools (Gathercole, 2007). In Welsh, there are numerous phonological changes in noun phrases when nouns have feminine gender, but fewer when nouns have masculine gender. Gathercole and her colleagues found that bilingual children's accuracy with noun phrases in Welsh varied directly with how much Welsh was spoken at home, but this variation was much more pronounced for the more complex feminine forms.

In brief, studies of the morphosyntactic development of bilinguals has shown that, given adequate learning environments, they acquire differentiated grammars from early in development and that their patterns of development in each language are like those of children acquiring the same languages monolingually. Some differences in morphosyntactic development have been noted and can take the form of actual deviations from monolingual patterns or simply atypical but nevertheless acceptable usage. Differences between simultaneous and monolingual learners in this domain of language learning can often be attributable to the context of language learning and, more specifically, how much exposure and what kind of exposure bilingual learners have to each language. Crosslinguistic differences in grammatical properties of each language can also play a role.

## Communicative competence

Studies of communicative competence were among the first to be carried out on simultaneous bilinguals beginning in the late 1980s. The motivation for these studies was to examine Volterra and Taeschner's (1978) claim that young simultaneous bilinguals go through an initial stage of development when their languages are undifferentiated. If this were true, then one would expect them to have difficulty using their languages appropriately with others. Specifically, you would expect them to use each language indiscriminately with conversational partners regardless of their partner's language competence or preferences. This should also result in extensive and random code-mixing during the same conversations, even with others who use only one language with them. However, systematic studies on this issue have revealed that even very young bilingual children use their two languages in morphosyntactically and communicatively competent ways; they are not confused. Research on this question has examined simultaneous bilinguals in early stages of development when they are producing mainly one- and two-word utterances because the unitary language stage was thought to occur early on, before full development in each language.

In an early study on this issue, Genesee et al. (1995) studied 2-year old children who were acquiring French and English simultaneously in Montreal from their parents, who claimed to use the one parent/one language pattern. These researchers found that the children used more of the mother's language with the mother than with the father and, conversely, more of the father's language with the father than with the mother. In a follow-up study, Genesee et al. (1996) found that similar simultaneous bilinguals (average age 2;2) were able to use their languages appropriately with strangers whom they had not met before, indicating that their ability to use their two languages differentially and appropriately was not dependent on prior experiences with their interlocutors. At the same time, the children participating in these studies used both languages at times with their interlocutors – for example, some French with the English-speaking parent and some English with the French-speaking parent. Detailed analyses of the children's use of code-mixing revealed that they were significantly more likely to mix languages when interacting with the parent or stranger who used the child's less proficient language (Genesee et al., 1995). This would suggest that code-mixing was used to fill gaps in their less developed language and, thus, that it is an indication of communicative competence and not linguistic confusion.

Young simultaneous bilinguals can exhibit impressive control over the use of their languages even though both are still in development. In another study of French-English bilingual children in Montreal (2;4 years of age on average), Comeau, Genesee, and Lapaquette (2003) found that the children adjusted their rates of code-mixing to match those of unfamiliar interlocutors who changed their rates of mixing from one occasion to another. In this scenario, the children were demonstrating a hallmark of communicative competence – the ability to adjust one's use of language to match that of one's interlocutor. That the children were able to do this while conversing with someone whom they had just met underlines that managing the use of two languages is not necessarily a burden for young simultaneous bilinguals. Finally, in a quasi-experimental study, Comeau, Genesee, and Mendelson (2010) found that 2- and 3-year old French-English bilingual children who used the "wrong language" with a monolingual interlocutor whom they had not met before switched languages when their interlocutors indicated that they did not understand what the child had said. Of particular interest, the children switched languages even when their interlocutors used a very general prompt, such as "What?", which did not indicate the source of the breakdown, indicating that managing their two languages was not a challenge. Taken together, this evidence is difficult to reconcile with the unitary language system hypothesis and the notion that simultaneous exposure to and acquisition of two languages can engender

confusion. To the contrary, these children exhibited remarkably sophisticated and appropriate communicative strategies at a very early age.

## Conclusions

While much more research is needed to reveal the full complexity of simultaneous bilingual development, extant research evidence reveals that newborns and infants are neuro-cognitively prepared to learn more than one language without difficulty provided the learning environment is adequate (see also Werker, 2012). Particularly striking evidence of this comes from research on children with developmental disorders that make language learning difficult. More specifically, studies of children with developmental language disorder and Down syndrome who are exposed to and learn two languages have shown that these children are able to achieve the same competence in their two languages as similar children learning only one language (see Kay-Raining Bird, Genesee, & Verhoeven, 2016; Paradis et al., 2011, for reviews). Because simultaneous bilinguals divide their learning time between two languages, the amount of exposure can be important, and, specifically, exposure below some minimum level is likely to yield diminished competence and altered developmental trajectories in one or both languages (Oller, Pearson, & Cobo-Lewis, 2007). However, extant evidence indicates that simultaneous bilinguals do not need as much time to learn each language as monolinguals have for learning one language in order to achieve remarkably similar levels of competence. This is evident in a number of ways. For example, bilingual learners, like monolingual learners, exhibit phonological fine-tuning between approximately 6 and 9 months of age; for the most part, they prefer to listen to words that conform to the phonotactic regularities of their input languages around 9 months of age; they can segment familiar words from continuous speech between 6 and 8 months of age; they are able to learn associations between new words and objects and events around 14 months of age; and they begin to produce their first words around 12 months of age, on average. Simultaneous bilinguals also exhibit patterns of morphosyntactic development that are similar to those of monolingual children learning the same languages. The similarities in these general developmental patterns as well as similarities in the relationships between different aspects of their developing languages, noted earlier, argue that the same underlying neuro-cognitive processes and strategies underlie and support dual language acquisition and monolingual acquisition.

At the same time, there are differences between simultaneous bilinguals and monolinguals (Conboy, 2013; Grosjean, 1989; Pierce et al., 2015). For example, simultaneous bilinguals have been found to tolerate irregularities in phonotactic constraints on spoken language in comparison to monolinguals, to exhibit delays in distinguishing some phonemic contrasts that are subtly different in their two languages, and, sometimes, but not always, to show crosslinguistic influences that are usually short-term. In many cases, the attested differences can be linked to complex and subtle linguistic differences in their two languages or to variations in the nature and quality of the input addressed to them and to the contexts of learning. Yet other differences attest to young learners' ability to accommodate the challenges of learning two languages simultaneously; this is evident in their use of language-specific prosodic patterns to bootstrap into the grammar of each language, their "violation" of the mutual exclusivity bias to acquire vocabulary in two languages, and their extended use of facial cues to distinguish their languages, among others. These differences can be seen as adaptive strategies used by young learners exposed to two languages to unravel and master the complexities of their developing languages. Studies of the communicative competence of young simultaneous bilinguals demonstrates that they are able to manage their two languages for communicative purposes with apparent ease and effectiveness. Taken together, these findings attest to the flexible and adaptive ways in which

the human neuro-cognitive system adjusts to the challenges of learning two languages in early childhood.

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## SECTION 3

# Individual differences in language acquisition



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# 17

# INDIVIDUAL DIFFERENCES IN LANGUAGE ACQUISITION

*Courtenay F. Norbury*

## Introduction

Language acquisition is a universal human phenomenon, and yet there is growing recognition that at every stage there exist considerable individual differences (IDs) in language competencies. IDs in the context of language acquisition can refer to quantitative and/or qualitative differences between individual language learners in the extent of learning in any of the expressive and receptive language domains (e.g. phonology, morphology, semantics, or syntax) or in how language is deployed in social contexts to convey meaningful messages between interlocutors (i.e. pragmatics; Norbury, Nash, Baird, & Bishop, 2004). IDs are apparent at every level of the linguistic system, from the timing of first words produced and the subsequent rate or trajectory of growth across language domains (Fenson et al., 1994; Frank, Braginsky, Yurovsky, & Marchman, 2017), to variation in the skills that underpin successful language acquisition such as sensitivity to abstract statistical properties in the ambient language (Siegelman, Bogaerts, Christiansen, & Frost, 2017). The study of IDs in language acquisition is critical: these differences emerge early in development and are powerful predictors of later academic and social success (Johnson, Beitchman, & Brownlie, 2010; Morgan, Farkas, Hillemeier, Hammer, & Maczuga, 2015). Understanding the sources of individual variation, how IDs change or are maintained over time, and how IDs in language influence IDs in other aspects of development, and vice versa, can inform both theories of developmental psychology, and practical efforts by education and clinical services to maximize children's language learning potential.

In this chapter, we document the breadth of IDs across multiple domains of language acquisition (see also Kidd, Donnelly, & Christiansen, 2018, for a comprehensive review). We then consider how IDs are related to two complementary forces in child development: stability and change (cf. Bornstein, Putnick, & Esposito, 2017). Factors contributing to stability and change are considered with regard to construct measurement and child-level, family-level, and societal-level (or contextual-level) influences. Finally, the implications of IDs in language acquisition for education and clinical services are considered.

## Individual differences in language acquisition

IDs are a common feature of human cognition as manifest in measures of attention, memory, and learning (Vogel & Awh, 2008). Thus, it is not surprising that IDs also characterize language

acquisition and skilled language processing. The extent to which IDs feature across all subsystems of language has been the subject of some debate (Kidd Donnelly & Christiansen, 2018), though there is accumulating evidence that IDs are evident in all expressive and receptive language domains and at every age across development (Bornstein, Hahn, & Putnick, 2016a, 2016b; Bornstein, Hahn, Putnick, & Suwalsky, 2014; Bornstein & Putnick, 2012). Seminal studies of language acquisition using the MacArthur Communicative Development Inventories (Fenson et al., 1994) highlighted large IDs in the onset and developmental course of gesture, spoken words, and early grammar in toddlers aged 8–30 months. Similarly, the Many Babies project (Frank et al., 2017) found stark differences in expressive vocabulary (around 400 words) at 30 months between toddlers at the 10th versus 90th centiles. Such wide individual variation in early acquisition has been consistently replicated (McGillion, Herbert, et al., 2017) and is evident in many different languages (cf. WordBank; Frank et al., 2017). IDs are also evident in grammatical development (Bishop, 2003b; Kidd, 2012) and emerging pragmatic/social communication skills (Norbury et al., 2004; O'Neill, 2007).

IDs can make it challenging to identify children whose language competencies fall outside of the expected range for age. Such children may be identified as having a developmental language disorder (DLD, formerly 'specific language impairment', or SLI; see Chapter 18, this volume and Bishop, Snowling, Thompson, Greenhalgh, & the CATALISE consortium, 2017). Typically, DLD is identified when children achieve scores on standard tests of language function that fall below an arbitrary cut-off (usually -1.25SD or the 10th centile, though the cut may be more or less severe), and their difficulties with language learning yield adverse functional impacts in everyday life. In this sense, IDs in language assume importance when extreme values increase the likelihood that a child will be disadvantaged within society because of poor language (Tomblin, 2006). Thus, while complex interactions between biological and environmental factors may give rise to IDs in language learning, the degree at which variation becomes a disorder is socially defined.

The extent of individual variation may be underestimated as studies of language development have tended to focus either on small, middle-class community samples with short-term follow-up (e.g. Rowe, Raudenbush, & Goldin-Meadow, 2012) or on large population studies of DLD which exclude children with pronounced social or biological risk factors, known developmental conditions, or non-verbal cognitive deficits (McKean et al., 2017; Tomblin et al., 1997). Notable exceptions include a series of studies by Bornstein and colleagues investigating language development in a large and diverse cohort of children from low-income families enrolled in Early Head Start programs in the USA (Bornstein et al., 2016a, 2016b). These studies measured a range of language skills in children from 15 months to 11 years of age. At every age and on every measure, assessment scores range from test floor to ceiling.

Similar findings were obtained in the Surrey Communication and Language in Education Study (SCALES: Norbury et al., 2016, 2017). SCALES is a population study of child language from school entry which screened a population of 7267 children and stratified a sub-sample by sex, season of birth, and scores on a teacher-report version of the Children's Communication Checklist-Short (based on the CCC-2; Bishop, 2003a). These children were assessed on six core language measures tapping receptive and expressive vocabulary, grammar, and narrative skill in Year 1 (ages 5–6 years) and Year 3 (ages 7–8 years) of primary school (Norbury et al., 2017). Unusually, the SCALES cohort includes children with DLD of unknown origin, and children with a range of developmental conditions that are associated with language, cognitive, and behavioral deficits (including autism spectrum disorder, chromosomal anomalies, etc.). Table 17.1 demonstrates IDs in vocabulary (Expressive and Receptive One Word Picture

*Table 17.1* Range of scores possible and obtained for each of six core language measures administered in Year 1 (ages 5–6) and Year 3 (ages 7–8) of the SCALES project (monolingual children only). Scores demonstrate wide variation in language attainment at each of these years of primary education.

| | | *Year 1 (ages 5–6 years) N = 529* | *Year 3 (ages 7–8 years) N = 499* |
|---|---|---|---|
| *Language domain* | *Possible test score range* | *Obtained* | *Score range* |
| Receptive vocabulary[a] | 0–190 | 21–114 | 28–153 |
| Expressive vocabulary[a] | 0–190 | 17–108 | 26–136 |
| Receptive grammar[b] | 0–40 | 0–32 | 0–37 |
| Expressive grammar[c] | 0–32 | 0–32 | 0–32 |
| Narrative comprehension[d] | 0–24 | 0–24 | 0–24 |
| Narrative retelling[d] | 0–35 | 0–23 | 0–27 |

*Notes:* [a] Receptive/Expressive One Word Picture Vocabulary Test (Bronwell, 2010). [b] Test for Reception of Grammar (adapted short version, Bishop, 2003b). [c] School-Age Sentence Imitation Test-E32 (Marinis et al., 2011). [d] Assessment of Comprehension and Expression-6–11, narrative sub-test (extended scoring for recall and novel comprehension questions based on the story) (Adams et al., 2001).

Vocabulary Tests, Bronwell, 2010), grammar (Test for Reception of Grammar, Bishop, 2003b, short version; School-Age Sentence Imitation Test-32, Marinis, Chiat, Armon-Lotem, Piper, & Roy, 2011), and narrative (Assessment of Comprehension and Expression 6–11 (ACE-6–11)), narrative sub-test, Adams, Cooke, Crutchley, Hesketh, & Reeves, 2001; bespoke comprehension questions (Norbury et al., 2017). These figures clearly demonstrate the wide range of language abilities that are represented in mainstream primary school classrooms in England. Notably, there are moderate to strong correlations amongst all composite language scores (ranging from .50 to .73), indicating that IDs across language domains are reliably related to one another (see also Kidd et al., 2017) and supporting the view that these measures tap a core language factor (Bornstein & Putnick, 2012).

It is also worth noting that by Year 3, children who started school at the bottom of the language distribution were only just reaching the levels of language competence that those children at the top of the distribution had achieved at the beginning of Year 1. Thus, the 'language gap' between those at the extremes of the distribution is approximately 2–3 years (see also Rice, 2013). Priority questions for clinical and educational services are whether it is possible to bridge this language gap, and, if so, whether there is an optimal age at which to do it. In order to answer this question, it is necessary to consider two complementary, but often apparently contradictory forces in child development: change (or development/growth) in a particular trait, versus stability of that trait over time.

## IDs in language stability and change

In developmental science, we are most often interested in change over time, in documenting children's increasing linguistic or cognitive capacities and their cascading effects on social, emotional, and behavioral well-being and/or academic success. At the same time, Bornstein et al.

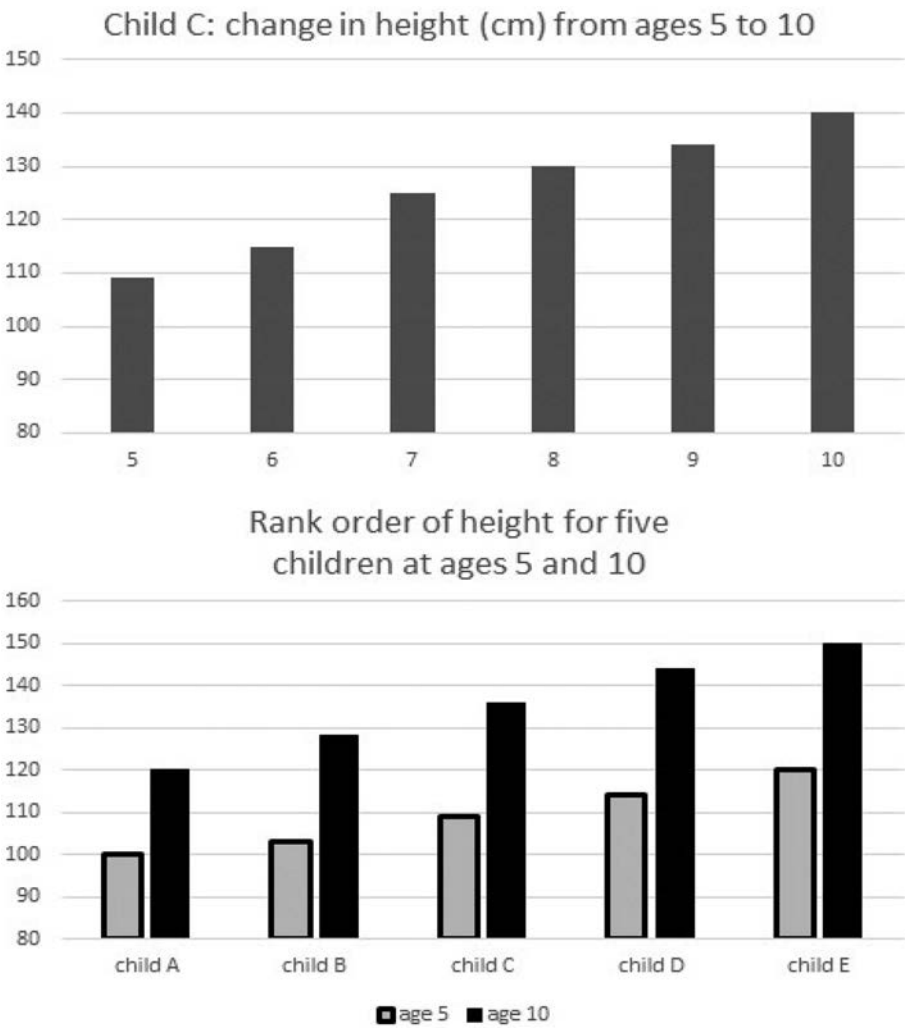



*Figure 17.1* Bar chart demonstrating that height, like language, changes over time in that an individual child will increase in height over time (top graph). At the same time, height is a stable trait. Child C maintains her position in the middle of the height distribution, as all children are getting taller and their average rate of growth is similar over time (bottom graph). Thus, even though all children experience growth, the rank order of individual heights in relation to one another is largely unchanged over this developmental period. Language appears to behave in similar ways.

(2017) make clear that developmental change can co-exist with individual-order stability; i.e. children may remain consistent in their rank order relative to one another over time on any particular skill set. Consider another familiar developmental trait – height.

In Figure 17.1 we see that if we were to measure an individual child's height between the ages of 5 and 11, we would most definitely see growth – children tend to get taller as they get older. However, the bottom graph illustrates that if we asked all the children in a given kindergarten (or reception) classroom to line up in order of relative height, there would be

considerable variation in the heights of children aged 5, with some relatively tall children and other relatively short children. If we were to repeat this exercise with the same children at age 10, we would see that all children had grown in height, but that the rank order of relative height would remain largely unchanged over this period: the relatively tall children would likely still be the tallest children in the class, and those that were short would still be relatively short, despite growing considerably.

Does language behave in similar ways? Answering this question requires longitudinal studies with repeated measurement of language over time. Change can be indexed by mean difference in test scores across time, using conventional benchmarks for interpreting the effect sizes of these differences (see Bornstein et al., 2017). Stability, which indexes the relative order of individual child language scores at each point in time, can be assessed at an individual level by using a standard or scaled score for a language test. In these cases we are asking how the child is performing relative to peers of the same age. For the most part, we would not expect a standard score to change much over time. For example, the 'normative' mean standard score of 100 on the Expressive and Receptive One-Word Picture Vocabulary Tests (Bronwell, 2010) is constant across ages, though the raw score required to obtain a standard score of 100 increases steadily over time. For children with language disorder, clinicians are often looking for an increase in standard score in response to a specialist intervention (Schmitt, Logan, Tambyraja, Farquharson, & Justice, 2017); this would indicate that the child had changed rank position and may be moving closer to the 'normal range' of ability on that measure. At a group level, stability is typically assessed using the correlations (and/or regression coefficients) between language scores at different points in time. Notably, even stable measures with a large correlation between Time 1 and Time 2 can still leave significant amounts of variation unexplained. For example, a correlation of $r = .70$ between two test points renders 51% of variation between those two points in time unexplained ($1 - r^2 = .51$). Even in samples such as SCALES where stability estimates are extremely high (.95), this still leaves almost 10% of variance in language at 7–8 years of age unexplained. Such small effects may yield important impacts, as even small IDs in other areas of development (e.g. non-verbal cognitive abilities, executive function, social understanding) may accumulate and assume significant influence on language trajectories over time (Bornstein et al., 2017).

Unfortunately, longitudinal studies to date have not routinely reported both change and stability, but doing so would give a more complete picture of the nature and influence of IDs in language development. Studies that have reported both have tended to report wide IDs in mean level change over time across development, while estimates of stability appear to alter over the course of development, in both typical language development (Bornstein et al., 2014; Bornstein & Putnick, 2012) and cases of social and/or biological risk (including cases of known neurodevelopmental disorder) (Bornstein et al., 2016a, 2016b; Pickles, Anderson, & Lord, 2014). Converging evidence indicates that language (or at least measurement of language) is less stable in the pre-school years compared to impressive rates of stability from school entry into adulthood.

For children aged 2 years and under at first assessment, language is not robustly stable during the pre-school years, and is not especially predictive of later language competence (Bornstein et al., 2016a; Duff, Reen, Plunkett, & Nation, 2015; Putnick, Bornstein, Eryigit-Madzwamuse, & Wolke, 2017). In these studies, stability estimates range from .23 (Putnick et al., 2017) to .65 (Bornstein et al., 2016a) and rarely above .50. Thus, variation in language ability at school entry is largely unexplained by language competence in toddlerhood. Despite different methods of assessing language and different approaches to statistical modeling, similar results of low language stability in the pre-school years obtain for children with potential language disorder (Eadie et al., 2014) and those with autism spectrum disorder (Pickles et al., 2014).

After the onset of formal education (typically between the ages of 4 and 6 years), language stability looks very different – across a number of studies and different populations, language is remarkably stable throughout the school years and into adulthood (Bornstein et al., 2014; Conti-Ramsden, St Clair, Pickles, & Durkin, 2012; Pickles et al., 2014; Rice, 2013). In these studies, estimates of language stability rarely drop below .85, despite many years between assessments and different methods of assessing language. Language trajectories (patterns of language growth) also appear to be more stable after this point in development; for example McKean et al. (2017) reported that 94% of children in their Australian population cohort demonstrated a 'stable' trajectory, with a remaining 4% demonstrating a 'low-decreasing' profile (4%) and only 2% demonstrating a 'low-improving' profile. This group was too small to draw firm conclusions, but it is notable that approximately half of the children from the 'low-improving' group came from non-English-speaking backgrounds. Thus, meaningful change in relative language ability appears rare at best. This does not, however, mean a lack of language growth in real terms; McKean et al. report that many children did demonstrate increasing language competence over time and that there was variation in progress within the stable trajectory group, with 22% of children increasing their language scores between the ages of 4 and 11 by >.75 SD. Despite this robust language growth, the rank order of individuals within the language distribution was largely unchanged.

Similar findings were reported by Pickles et al. (2014), who documented the language trajectories of 192 children with autism spectrum disorders between the ages of 2 and 19 years, using parent report of receptive and expressive language on the Vineland Adaptive Behavior Scales (Sparrow, Cicchetti, & Balla, 2005). In this population, latent growth classes revealed seven distinct classes of language growth, all of whom demonstrated improvement in absolute language function over time. However, there was considerably more variation in improvement prior to age 6. During this early developmental period, 22% of children (3% total catch-up, 19% partial catch-up) started with very low initial levels of language, but demonstrated accelerated language growth such that they were able to overtake peers. A smaller percentage (5%) showed a declining trajectory, in which an initial promising start was not maintained. These variations in trajectory were short-lived; after the age of 6 all seven classes tracked in parallel, with the majority of children showing persistent and considerable language deficit.

A combination of wide IDs in language ability at every developmental stage coupled with a changing developmental pattern of language stability poses considerable challenges for the identification and treatment of children with low levels of language proficiency (and thus potential cases of DLD). On the one hand, reduced stability in the pre-school years means that early low scores on language measures are not necessarily predictive of long-term language needs. Indeed, Bornstein et al. (2016a) concluded that '15 months is too early to form reliable skill groups that predict later outcomes' (p. 15), while Duff et al. (2015) argued that 'the stability of vocabulary skills from infancy to later childhood is too low to be sufficiently predictive of language outcomes at an individual level' (p. 848). Thus, early diagnosis of language disorder in the preschool years is unlikely to be reliable and requires multiple assessments to determine the likely prognosis (cf. Eadie et al., 2014; Bishop et al., 2017). In addition, providing early intervention to late talkers (in the absence of other known risk factors; see Bishop et al., 2017 for an overview) may not be cost-effective, as many children make considerable progress in language without any additional support (McGillion, Pine, Herbert, & Matthews, 2017; Wake et al., 2013).

On the other hand, the impressive stability of language after school entry can paint a rather bleak picture for children who start school with low levels of language proficiency. Research consistently demonstrates that language deficits evident at school entry persist throughout primary school (McKean et al., 2017; Norbury et al., 2017) and adolescence (Bornstein et al., 2016b; Conti-Ramsden et al., 2012; Law, Tomblin, & Zhang, 2008), and into adulthood (Rice,

2013). Notably, though, individual stability (a given child's relative position within the population) is uninformative about whether, and how much, within person change has occurred during that developmental period (cf. Bornstein et al., 2017). Longitudinal studies of children with DLD confirm meaningful change in language capacity throughout primary education. Intriguingly, the rate of growth appears to be similar at either end of the language distribution; thus, an initial 'language gap' of approximately two years is maintained throughout the school years (Norbury et al., 2017; Rice, 2013), with little evidence that children are able to 'catch-up' with more language able peers (Conti-Ramsden et al., 2012).

To return to our height metaphor, language behaves like height in that both are (for the most part) normally distributed within the population, both are subject to genetic influences (you can tell who the tall children will be by looking at their parents, and child language too is influenced by genetic and environmental factors; Newbury & Monaco, 2010), and for both height and language, potential disorders are determined by arbitrary cut-offs (measured height or scores on standard tests of language), in combination with the functional impact of extreme values on daily living. In addition, there are large IDs in initial growth spurts for language and height, and early variation in growth trajectories. Once children arrive at school, language, like height, continues to grow at a steady pace, though there may well be non-linear rates of growth during puberty. Nevertheless, language, like height, is largely stable from this point. Children with greater language proficiency at school entry tend to maintain their linguistic advantage throughout the school years. Those with low levels of language proficiency, many of whom may meet criteria for DLD, will continue to have relatively poor language skills, as their rate of language growth parallels, or tracks, that of peers (Law, Tomblin, & Zhang, 2008). Current research findings suggest that around school entry we are better able to predict those children who may need additional support to develop the oral language skills that will be critical to academic success and the development of proficiency with written language (Klem, Hagtvet, Hulme, & Gustafsson, 2016). Critical questions for the field are what factors act to maintain or disrupt stability and change of IDs in language, and can these factors provide mutable targets for intervention?

## Factors that maintain or disrupt stability

A focus on IDs naturally gives the impression that stability and change are likely due to characteristics of the individual and their responses to environmental inputs. However, stability and change are relative measures, not absolute and not determined solely by child-level factors. Instead, stability may be influenced by child-level IDs in other aspects of neurobiological, cognitive, and social development, family-level factors that may serve to increase variation amongst children with regard to the language input they receive, and broader societal or contextual factors such as schooling. First and foremost, measurement of language and the statistical models used to evaluate stability and change will also affect their estimates. In combination, these factors can make it exceedingly difficult to know whether change (or lack of change) in language competence reflects inadequate measurement and/or measurement error, changing social and educational contexts, practice or familiarity effects, real change (developmental or in response to an intervention), or other interactive developmental processes. Methods for beginning to disentangle some of these issues are discussed here.

### *Measurement*

The first issue of measurement centers on which component of language to assess. Many studies have taken a univariate approach, considering growth and stability in vocabulary (e.g. Rowe

et al., 2012), grammar (e.g. Rice, Hoffman, & Wexler, 2009), or discourse skills (Adams & Lloyd, 2005). While all such measures show moderate estimates of stability, these vary somewhat depending on the domain assessed, the properties of the assessment, the method of assessment (i.e. direct assessment versus parent or teacher report), and the interval between assessments.

All instruments are subject to measurement error, reflecting the distance between a child's measured language score and true language score that arises from random error in test accuracy, or systematic error in less robust measures. Thus, the accuracy of estimates of stability and change critically depends on having robust and reliable assessment instruments. In order to obtain accurate estimates of stability and change, we need to select reliable measures with sufficient items to capture IDs in growth over time. This is particularly important to bear in mind when considering more experimental measures of language learning or language processing; experimental tasks of language processing typically aim to minimize variation in performance between individuals in order to be more reliable at the group level (Hedge, Powell, & Sumner, 2017) and thus tend not to have adequate levels of test-retest reliability, despite showing robust effects at a group level. Reduced reliability will attenuate correlations between tasks over time. At first blush this suggests more instability in the construct under investigation, when in fact it may simply reflect more measurement error.

Method variance is an important consideration in interpreting stability estimates (Tamis-LeMonda, Kuchirko, Luo, Escobar, & Bornstein, 2017). Stability estimates will be increased when the temporal distance between measurement points is minimal and when the same measures are used repeatedly over time; changing assessments at different developmental points will yield lower estimates of stability. Similarly, ratings from the same informant over time, or from the same informant across different instruments, will likely increase correlations amongst these measures. Thus, in addition to test-retest reliability, understanding the inter-rater reliability of instruments is a necessary step to interpreting estimates of stability and growth when different raters are required to provide evidence at different points in time (e.g. Year 1 versus Year 3 teachers, or parents versus teachers). Unfortunately, across a range of developmental rating scales, inter-rater reliability estimates comparing parent-teacher responses are disappointingly low (Gooch, Maydew, Sears, & Norbury, 2017). This is likely due to the differing knowledge, expectations, and reference groups that influence different raters, and will attenuate estimates of stability and change.

Language is typically viewed as componential, and until recently, clinical distinctions were made with respect to receptive and expressive language skills (cf. ICD-10). Traditionally, different components of language have been assessed using different tests, which usually have distinct normative samples and varying estimates of measurement error. An added consideration is that many potentially clinically meaningful language measures yield bimodal, rather than normal, distributions (Rice, 2003), and growth trajectories are not all linear. For example, while vocabulary follows a linear growth trajectory from 4 to 20 years, appropriate marking of grammatical tense in spontaneous speech yields a different distribution, with a sharp rise in proficiency to near adult levels at just below 90%, usually between the ages of 3 and 5 in typical language development (Rice, 2013). To further complicate matters, the nature of the language to be measured changes dramatically over time. For infants and toddlers, parent report of words expressed or understood is often the limit of what we can directly measure. As children get older, we are interested in use of syntactic forms, abstract language, and extended discourse. From a developmental perspective, we may want to know whether early IDs in the onset and accumulation of single words are meaningfully predictive of later IDs in these more complex language forms and usages. Direct comparison of stability and growth across assessment measures therefore presents considerable challenges. Nevertheless, different components of language reliably correlate with

one another and tend to load on a single 'language factor' (Tomblin & Zhang, 2006). This is recognized in the most recent revision of DSM-5 (American Psychiatric Association, 2013), which no longer differentiates between receptive and expressive language disorder.

Due to the considerable measurement challenges, researchers increasingly employ latent variable techniques to study stability. Latent variables can incorporate a variety of assessments ostensibly tapping different components of language, and can accommodate different assessment methods and respondents. Thus, one can combine parent report of everyday language use (e.g. the Children's Communication Checklist-2) with direct assessment of receptive vocabulary and expressive grammar, to identify an underlying latent construct of 'language'. Latent variables have the added advantage that they yield more precise statistical estimates, because they distinguish shared variance amongst measures that are common to language, but relegate variance that is uniquely associated with extraneous factors such as measurement error, rater bias, or measurement specific issues to a residual error term. Latent variables of language ability thus permit comparison of the underlying construct over time, allowing for different age-appropriate assessments to be used at each time point while preserving comparability of the core construct, undiluted by the measurement error associated with specific assessments (for more detailed review of latent variable models applied to the study of child language development, see Putnick & Bornstein, 2016).

The outcome of a latent variable model depends largely on the integrity of assessments included in that model. To be clinically and educationally meaningful, the assessments used should be psychometrically sound, with adequate levels of reliability and validity. The reliability of the instruments included in the latent variable model set a limit on statistical estimates of stability and change (Bornstein et al., 2017); less reliable measures will yield lower estimates of stability and thus have less predictive validity in gauging later language outcomes.

With these challenges in mind, it is interesting to consider whether reported instability in language prior to school entry reflects meaningful developmental differences in neuroplasticity and capacity for change, as has been suggested (Bornstein et al., 2016a; Pickles et al., 2014), or whether lower levels of stability at pre-school reflect reduced reliability of language assessment in young children, coupled with the often necessary change in testing methods from parent report to direct assessment between pre-school and school-age.

## *Child-level factors*

As noted at the beginning of this chapter, there are large IDs in language proficiency from the earliest ages of language acquisition, and these IDs may themselves contribute to variation in language stability and language change (Bornstein et al., 2014). This is because early stable child characteristics shape the development of later characteristics. The SCALES sample provides an illustration of this: even by the end of the reception year (ages 4;9–5;11), children with language deficits were rated by teachers to have more symptoms of social, emotional, and behavioral deficit (Norbury et al., 2015). Such deficits, in combination with lower levels of language skill, affect the child's interactions with peers and his or her ability to learn effectively in the classroom. By Year 3 (ages 7–8), many of those children with the most extreme language deficits were in alternative educational provisions, had significant peer problems, and had limited levels of literacy (Norbury et al., 2017). Such children therefore engage with and interpret the world differently and elicit different responses from peers and caregivers, and the content and manner of academic instruction they experience is considerably different to that of those children who start school with more advanced levels of language proficiency (see also Morgan et al., 2015).

One may therefore consider whether IDs in other child characteristics may modify stability and change in language. In the SCALES study (Norbury et al., 2017), we examined the extent to which non-verbal cognitive abilities, and ratings of social, emotional, and behavioral difficulties, affect the rate of growth in language scores over the first three years of primary school. The results were very clear: both non-verbal ability and behavior were associated with language intercepts, such that children with more severe language disorder also had, on average, lower non-verbal ability scores and more symptoms of social, emotional, and behavioral deficits. However, neither of these metrics were associated with slope; children at the bottom of the distribution as a group experienced parallel rates of growth to those at the top, at least during this period of development. Bornstein and colleagues (Bornstein et al., 2016a, 2016b; Putnick et al., 2017) provide a more nuanced developmental picture. In these studies, children with multiple biological risks showed greater stability estimates relative to peers from the ages of 15 months to 5 years, but similar stability estimates across different language skill levels after school entry. Furthermore, even in the early years, stability was not influenced by exogenous factors such as home environment (see section on family-level factors, below). This pattern of findings leads the authors to surmise that at younger ages, children with lower levels of language proficiency may be more influenced by child-level, as opposed to environmental, factors (Bornstein et al., 2016a, 2016b). In contrast, at older ages stability was similar across language skill (Bornstein et al., 2016a) or risk groups (Bornstein et al., 2016b; Putnick et al., 2017), and not influenced by child-level IDs in non-verbal intelligence or positive social interaction.

Such findings lead to the provocative suggestion that similar processes maintain core language whatever the level of language competence (Bornstein et al., 2016a, 2016b). If children with impoverished language experienced greater stability at all points in development, this might suggest different underlying processes and perhaps inherent limits on language learning capacity. The fact that language growth for lower skill groups appears to track that of more able peers further suggests that while language learning itself may be malleable, the rate at which children learn language may not be. This has significant implications for intervention, which may focus most profitably on the type and intensity of language input the most vulnerable children receive.

## *Family-level factors*

Many theories of language acquisition consider the central role of caregivers within the child's learning environment in providing the right type of linguistic input at the right time to drive language learning (Montag, Jones, & Smith, 2018). These theories posit that children come to the task of language learning with little innate language-specific knowledge, and must derive words and rules from analysis of, and generalization from, the ambient language within their environments. On this view, variation in the language learning environment would contribute to IDs in language acquisition and language processing. Variation in language learning environments could include the quantity of language a child hears (and particularly the amount of language directed at the child), the quality or diversity of language a child hears, and the quality or contingency of caregiver responses to child communication attempts, all of which contribute uniquely and meaningfully to language acquisition.

Numerous investigations have documented associations between the amount of child-directed speech a child hears in infancy and that child's spoken language proficiency in toddlerhood (Weisleder & Fernald, 2013) and beyond (Rowe et al., 2012). Such findings also extend to broader aspects of adult communicative behavior; parents who gesture more also have children with more advanced vocabularies (Rowe, Ozcaliskan, & Goldin-Meadow, 2008). More recent investigations have highlighted the importance of the diversity of contexts in which children are

exposed to language as another factor that is predictive of the quantity and quality of early child language (Montag et al., 2018).

A common theme of these investigations is that early proficiency in one domain of language (e.g. vocabulary) has cascading impacts on other aspects of verbal (e.g. grammar) and written (e.g. reading comprehension) language development, which in turn provide more opportunities for language learning (Lervag, Hulme, & Melby-Lervag, 2017). Thus, early IDs in the acquisition of first words and phrases, associated with IDs in parental language input, will manifest as IDs in later grammatical competencies or success in reading and may further serve to increase overall stability of language function.

While associations between parental language input and child language competencies are ubiquitous, they remain that, associations. A popular view is that limited parental input 'causes' limitations in child language competence. Here we must remain mindful that language is an interactive learning endeavor; parental language is influenced both by parent characteristics and by the extent to which children actively elicit language from their parents. For example, the association between child gesture and child vocabulary is largely driven by the extent to which pointing gestures prompt naming behaviors from caregivers (Rowe & Goldin-Meadow, 2009). Thus, children who are less likely to explore their environments or initiate communication using gesture or vocalization may in turn receive less language input from caregivers. In these cases, IDs in language input may reflect child-level IDs in language or social engagement, rather than family-level variation in language competence.

Proxy measures of parental engagement, such as maternal education and socio-economic status (SES), are clearly associated with IDs in language, but more variable in their association with language change and stability. Higher levels of maternal education have been associated with higher levels of maternal language competence, the overall quantity of child-directed language, and the quality of parent responses to child communication attempts (McGillion, Pine, et al., 2017; Pan, Rowe, Singer, & Snow, 2005). Similarly, SES has been broadly linked to large family-level differences in the amount of language children hear. Seminal studies by Hart and Risley (1995) indicated that children from the lowest socio-economic strata hear on average 30 million fewer words by the time they start school compared to children from the highest SES strata. These SES differences in language input are evident by the second year of life (McGillion, Pine, et al., 2017) and have lasting associations with child language and later educational attainment (Duncan & Magnuson, 2012). Note that SES may also index family-level variation in non-communication variables, such as access to housing, adequate nutrition, and healthcare, that may also affect brain development (Farah, 2017) and thus IDs in language capacity.

Such family-level factors go some way to understanding IDs in the initial stages of language acquisition; an important next question is whether family-level factors affect rates of language change or stability. Does consistency in family circumstance yield higher estimates of language stability, or the corollary, do more chaotic home environments yield lower estimates of language stability? There is limited evidence that this is the case. In SCALES, while SES was associated with language intercept, it was not associated with the rate of language change over a two-year period (Norbury et al., 2017). Similarly, Bornstein et al. (2016a) demonstrated higher stability estimates for children with lower levels of language competence compared to more able peers before age 5, but minimal association with indices of the home environment, maternal language, or maternal education. These findings suggest that prior to school entry, IDs in language competence may be more influenced by child-level, as opposed to family-level, factors. After age 5, stability estimates were strong and similar across the two language skill-level groups, independent of variation in family-level factors. It may be that the advent of school introduces more homogeneous

environmental experiences that exert greater influence on language growth at this stage and attenuate the impact of individual child-level or family-level characteristics.

Taken together, this body of research suggests that introducing small changes in the quantity and diversity of language children hear within the family context could yield large gains in child language learning. For example, Montag et al. (2018) created language learning environment simulations based on data within the CHILDES corpus to explore the impact of different kinds of language exposure on the diversity of word tokens to which a child is exposed. Their computational models suggested that introducing an additional 10 storybooks per month to children increased the number of unique words a child was exposed to by about 2%. These findings accord well with evidence that dialogic book reading interventions have (at least a short-term) positive effect on children's oral language skills (Mol, Bus, & de Jong, 2009). The positive impacts of shared book reading on language may in part reflect the fact that books include references to extraordinary contexts and events, and decontextualized talk about the book takes language away from the here and now, both important for increasing the diversity and complexity of language a child hears (cf. Montag et al., 2018). Parents can also be trained to provide more contingent responses to child communication initiations, with immediate impacts on expressive vocabulary (McGillion, Pine, et al., 2017). This study also provides provocative evidence that the impacts of such interventions may be particularly salient for families from disadvantaged backgrounds. However, whether such impacts have long-lasting influences on child language growth and stability, or indeed the predicted cascading impacts on other domains of language, is much less clear. McGillion, Pine et al. (2017) report that initial language gains were not maintained a year after the brief intervention period. It is also worth noting that even fairly dramatic change in language in real terms may not shift stability; children with lower levels of language competence may still remain at the bottom of the language distribution despite significant language growth if the gap between them and their more able peers is sufficiently wide. The changing and interactive nature of language further suggests that family-directed interventions may need regular support and updating to enable caregivers to meet their child's changing language needs.

## Societal (context) factors

The bulk of research regarding IDs in language acquisition has been conducted in white, Western, English-speaking countries. While there are certainly cultural differences in the expectations for parent-child interaction (Norbury & Sparks, 2013), the impact of diverse cultural expectations on IDs in language acquisition is woefully under-researched. Cultural differences in language change and stability may exist, but we have limited cross-cultural evidence with which to answer this important question. A handful of studies of developing bilinguals appear to suggest that when learning English as an additional language, bilingual learners are more likely to show greater than expected rates of improvement in English language capacity, relative to monolingual speakers with similar levels of English language proficiency (McKean et al., 2017; Whiteside & Norbury, 2017).

As noted previously, a consistent finding across studies and populations is that estimates of language stability increase substantially from the ages of approximately 4–6 years (Bornstein et al., 2014; Pickles et al., 2014). The increased reliability of assessment measures in older children is likely one contributing factor to increased stability, but another consideration is the onset of formal education. Education provides greater homogeneity of language input and reading experience, as well as explicit instruction in vocabulary and grammar that may attenuate the impact of IDs in statistical learning, and may therefore (paradoxically) reduce variation in the rates at which different children make progress in language learning. This can be positive, as

children with multiple learning challenges can continue to make progress in language learning, often at the same rate as more able peers (cf. Norbury et al., 2017). However, 'narrowing the gap' between the most able and the most linguistically disadvantaged children appears to be very challenging after school entry. IDs in language proficiency at the start of formal education are therefore maintained throughout children's academic careers, with an average of a 2–3-year 'language age' gap from school entry to adulthood (Rice, 2013).

## Implications for education and intervention services

The goal of many specialist education provisions and clinical (speech-language therapy) services is to accelerate language change for those children at the bottom of the language distribution, such that one might aim to 'normalize' a language trajectory, 'narrow the gap' with more able peers, or demonstrate 'greater than expected' progress on key language indices. Achieving these goals requires us to understand how much natural change can be expected on particular measures over a given period, yet we currently lack sufficient longitudinal data to give us reliable estimates of how much change is naturally expected (Schmitt et al., 2017). Nevertheless, our expanding research evidence base focusing on language stability and change provides important educational and clinical insights.

The first is that good, universal education provision likely supports the steady growth of language skills for all children from school entry and increases language stability over developmental time. Narrowing language gaps therefore appears to be challenging once children are in full-time education (Bleses et al., 2017). However, we do have increasing evidence that language learning itself remains malleable across the lifespan (Romberg & Saffran, 2013), and adolescence is identified as a potential sensitive period for brain development (Fuhrmann, Knoll, & Blakemore, 2015) and cognitive change in response to intensive, targeted training (Knoll et al., 2016). An open empirical question is what type of input and, crucially, what dosage would be sufficient at this age to disrupt language stability and perhaps reset a developmental trajectory. A more realistic goal of most school-age therapy services, however, may be to embrace IDs in language proficiency and consider instead how to ensure that children with limitations in language can fully participate in curricular and social activities, and how to mitigate potentially negative downstream consequences of language disorder, such as poor literacy (Snowling, Duff, Nash, & Hulme, 2016), social, emotional, and adverse mental health outcomes (Yew & O'Kearney, 2013), limited employment options (Conti-Ramsden, Durkin, Toseeb, Botting, & Pickles, 2018), and increased association with delinquency (Hughes et al., 2017).

The research evidence is also clear in suggesting that the level of language that children possess when they start school is likely to set the developmental pathway going forward. Efforts to narrow the language gap may therefore most fruitfully be directed at pre-schoolers between the ages of 3 and 5, when language skills are beginning to gel and become more predictive of later language (Bornstein, 2014; Bornstein et al., 2016a, 2016b). However, even the most promising pre-school intervention programs require intensive, targeted input over a prolonged period, and yield at best modest gains in language capacity (Fricke et al., 2017; Hagen, Melby-Lervag, & Lervag, 2017; Haley, Hulme, Bowyer-Crane, Snowling, & Fricke, 2017). Importantly, these modest gains do appear to be maintained over time, and limited transfer to literacy has also been documented (Hagen et al., 2017).

Limited language stability prior to age 3 has suggested to some perhaps a period of enhanced neural plasticity when efforts to change a developmental language trajectory may be most efficacious (cf. Pickles et al., 2014). However, IDs in the onset and initial growth of language skills, coupled with reduced reliability of language assessment at this developmental stage, may obscure

real change from noise in the data. Putting all of our eggs in an early intervention basket may result in 'treating' many typically developing children (Norbury, 2015). And indeed, randomized controlled trials for late talkers selected from the general population have failed to produce significant clinical effects, largely because the no-treatment control group makes just as much progress as the intervention group (Wake et al., 2011, 2015). However, higher rates of language stability during the pre-school years for children with lower levels of language competence drawn from populations with biological and social risks (Bornstein et al., 2016a, 2016b) indicate that prioritizing early intervention for children from these more vulnerable backgrounds may be critical to reducing language-related disadvantage later in development. Increasing the amount of language these children hear, as well as the diversity of contexts in which they hear language, and improving the quality of contingent responses to child communicative attempts present as the most promising avenues in which to instigate changes to language stability for these children. On-going support for parents will be required to effect change here as brief interventions do not tend to yield sustained change in child language (McGillion, Pine, et al., 2017).

## Conclusion

IDs in child language are pervasive and reflect both variation in the biological mechanisms children bring to the task of language acquisition, and variation in the communication environments in which children are enveloped. Early IDs in language acquisition influence the development of later language and cognitive skills, which in turn affect further language learning. IDs in language tend to become more stable after the onset of formal education and are associated with IDs at the child, family, and societal levels, though stability of language maintains even when these endogenous and exogenous variables are taken into account. Educational and clinical services often aim to change language trajectories in order to minimize IDs between the most able children and those with lower levels of language proficiency. High rates of language stability indicate that this may be an unrealistic goal; though language remains malleable, greater than expected improvement relative to peers remains elusive. The weight of evidence presented in this chapter tells us that although language remains malleable throughout the lifespan, the rate of language learning may be less so. Practically, for families and practitioners this can be frustrating, and it can be challenging to determine if change in a child language assessment reflects an expected rate of developmental change, or fluctuations in performance associated with measurement issues, practice effects, or indeed that elusive enhanced growth in language resulting from a specific intervention or change in input. Theoretically, similar rates of language growth for children across the spectrum of language ability strongly suggest that the core mechanisms that maintain IDs in language over developmental time are similar across the distribution, despite significant variation in biological and environmental endowments experienced by different language learners.

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# 18

# DEVELOPMENTAL LANGUAGE DISORDER

*J. Bruce Tomblin*

The chapters in this book address a number of different issues regarding features of language development by children. This chapter and the others in this section focus on the fact that although the development of language is nearly universal, there is substantial variation in the ease with which children accomplish this remarkable feat. As noted by Norbury (Chapter 17, this volume), this variation can be seen across the spectrum of language abilities, and thus we can conceive of a multidimensional space representing the language and communication abilities of children at any point in development. It shouldn't be too surprising that this variation has functional consequences in the lives of children. That is, children occupying a particular region in this space may face challenges and penalties arising from limitations in language and communication ability. Furthermore, although basic facility with communication has likely been an important aspect of human function for centuries, our current society has elevated the demands placed on both written and oral communication. Therefore, language ability is becoming an increasingly critical determinant of human capital in our society. Thus, poor language abilities are likely to bring ever-increasing penalties in an age of information. In this chapter I will focus on a group of children who find themselves in a region of poor language ability that was not predictable during infancy and for which we have little explanation once it emerges. For the most part, these children appear to be very similar to most other children in most regards, and thus clinical concerns over these children occur as a result of conditions such as speech sound disorder, reading disorder, or attention deficit hyperactivity disorder (ADHD) that are often associated with the poor language. In the pages to follow, I will attempt to provide a narrative account of my current understanding of who these children are and how they differ from those who do not provoke clinical concern.

This narrative begins with my general framework for understanding developmental language disorders in general, but I will focus on this subgroup of children with unexpected and unexplained language disorder. This framework begins with individual differences in language and communication ability and function viewed as occupying a potentially multidimensional ability space, as was foreshadowed above. I have come to do this in order to emphasize that children with language disorder do not belong in a separate universe from children in general and that variation in ability is much more continuous than lumpy or categorical. Furthermore, there is likely to be more variation within regions of the "normal" ability space than in the region considered to be aberrant or disordered. When viewed this way, we come to appreciate that the

fundamental concepts that go into understanding the development of these children who have poor ability are likely to be the same as for those with better abilities.

## What shall we call these children?

Children with unexpected and unexplained poor language have been described for well over 150 years. During this time this group has been called aphasic children, language delayed, children with speech, language and communication needs (SLCN), specific language impaired, and developmental language disordered along with other labels. It is somewhat ironic that for a developmental disorder involving language, we seem to lack an acceptable word to refer to this condition. The term "aphasic" was prominent into the 1970s; however, its suggestion of a neurogenic etiology and the terminological overlap with acquired language disorder due to focal lesion led to a search for other terms. "Language delay" was briefly a candidate term; however, this term suggested that the condition was temporary; however, research in the 1970s was beginning to show that it persisted through childhood. Beginning in the 1980s, the term "specific language impairment" (SLI) was introduced by Stark and Tallal (1981) and soon thereafter by Fey and Leonard (1983). One feature of this term was that in addition to the absence of co-occurring sensory and neurodevelopmental conditions, these children were required to have normal intellectual function, as often reflected by a normal nonverbal IQ. Thus, in many research settings, children with SLI were selected to have language abilities that were clearly lower than their nonverbal abilities. This requirement of a discrepancy between language and nonverbal IQ was incorporated into the ICD-10 (Organization, 1992). By the start of the new century, "SLI" had become a widely used term, particularly in the research community. However, there were also a substantial number of voices expressing concern, particularly over the adequacy of the term and its associated diagnostic criteria that required normal levels of nonverbal IQ.

In 2013 the DSM-5 (American Psychiatric Association, 2015) was published, and this group of children were referred to as children with Language Disorder. This resulted in a large number of researchers and clinicians engaging in a series of papers on the question of whether "SLI" or some other term such as "language disorder" was most appropriate for these children (Bishop, 2014; Reilly, Bishop, & Tomblin, 2014; Reilly, Tomblin, et al., 2014). Those who argued for the term "specific language impairment" noted that this term had an established history and research base; both research and clinical setting needed a term that was generally understood. The argument against continuing to refer to these children as having SLI had to do particularly with the notion of "specific". When this was applied to clinical practice, this resulted in a large group of children with poor language and nonverbal skill being excluded from clinical services. The use of this nonverbal ability requirement was challenged by several authors (Dale & Cole, 1991; Lahey, 1990; Plante, 1998) as being neither conceptually well founded nor supported by empirical data. Given these arguments, those supporting a move away from SLI expressed the concern that "SLI" was not an accurate term for these children and had the effect of excluding those with no discrepancy from clinical and research efforts. Subsequently, a project (CATALISE) organized by Dorothy Bishop (Bishop, Snowling, Thompson, Greenhalgh, & Consortium, 2016, 2017) was recently conducted to survey a large sample of researchers and clinicians with regard to viewpoints about the name for this group of children and the characteristics that would contribute to a diagnosis. This process resulted in a general consensus that the term "developmental language disorder" most accurately described these children and that the developmental skills of these children were not restricted to language, but that the poor language placed these children at risk for future problems. Throughout this chapter, I will use the term

"developmental language disorder" (DLD) to refer to these children, acknowledging that the research I will draw upon frequently has referred to them as having SLI.

## Dimensions of communication ability in children

Regardless of what we call these children, we have to agree that they belong to a universe of individuals going through the process of language development. At any one point in development, these children differ with respect to their language ability or abilities from other children who have better abilities. This brings us to the question, how many ways can children differ from each other in language development? Within individual differences research this is often viewed as a question of the number of dimensions this domain contains and then what the nature of these dimensions is. Over the past half century or so, language and developmental sciences have constructed a wide array of measures of different aspects of children's language. These have often been derived from linguistic theory that yields a large descriptive vocabulary for what goes into language and communication. It is possible that for each construct of language there is an underlying ability trait that can have its own developmental trajectory. If so, the hypothetical multidimensional space may be vast. Psychological measurement theory concerned with multivariate characterization of human performance has distinguished between behaviors on the surface – manifest measures – and latent traits that underlie these manifest measures. In most areas where this has been applied, such as personality or intelligence, the number of latent traits is often substantially lower than the number of manifest variables. Unfortunately, research in child language development has not employed this approach very often, and therefore we don't have a strong empirical base to tell us what the likely latent language traits are or what their characteristics are. One exception can be found in the work of Colledge and colleagues (2002). This study examined the factor structure of several measures of language, articulation performance, and nonverbal IQ in a large sample of 310 pairs of twins. A factor analysis suggested that there were three principal components reflecting three factors. An oblique rotation of these three factors showed that all the language measures loaded on one factor, the nonverbal IQ measures loaded on a second factor, and the accurate articulation of words and nonwords loaded on a third.

On a few occasions, I have had the opportunity to have sufficiently large data sets with a modest array of measures of language that were gathered from a large sample of children who were first recruited as kindergarteners, and then a subgroup was followed through the school years. One of these studies (Tomblin & Zhang, 2006) focused on measures of lexical and sentence use (listening and speaking) obtained at kindergarten, second, fourth, and eighth grades. Across the grades we generally found that the measures loaded on one factor. As the children grew, we did find a partial separation of vocabulary and sentence use; however, these traits remained correlated. At no point did we find evidence of factor structure reflecting a comprehension-production distinction. This is important, because this distinction has been prominent in classifying subtypes of DLD. Missing from these analyses were measures of speech sound production ability; however, other work we have performed with this sample (Tomblin & Zhang, 1999) has supported the findings of Colledge and colleagues that speech sound production abilities are relatively independent of language skills comprising vocabulary and sentence use. These studies have provided evidence of a single latent trait of language based on measures of vocabulary and sentence use and a separate trait that reflects speech sound production abilities (see Chapter 19, this volume). Subsequent to these studies, there have been three similar studies, and in all cases they also found a single latent trait underlying the various manifest measures of vocabulary and sentence use (Anthony, Davis, Williams, & Anthony, 2014; Bornstein & Putnick, 2012;

Consortium, 2015). In the Anthony et al. study, evidence for a separate trait of speech sound production was also replicated.

The measures of communication in the studies above did not incorporate the interpersonal social aspect of communication often referred to as pragmatics. We have examined this in a couple of studies. This work used data obtained when a subgroup of the children examined as kindergarteners was followed into second grade, where measures of social use of language (pragmatics) were available (Tomblin, Zhang, Catts, Ellis Weismer, & Weiss, 2004). This study revealed that these measures of social use of language appeared to reflect two separate dimensions (appropriateness and engagement) that were distinct from a language dimension measured by vocabulary and sentence use. Two other dimensions, concerning phonological processing and nonverbal IQ, were also present. What these examples show is that the likely latent ability space that contains the individual differences in language among children during development is rather limited. Across studies, likely three dimensions involving language form and content, pragmatics or language use, and speech sound production seemed particularly robust. Children with DLD would represent children who are low particularly on the language dimension. More recently, we looked at the dimensionality of standardized language measures concerned with vocabulary and sentence use, along with several measures of spontaneous language (Tomblin, Nippold, Fey, & Zhang, 2014). The results of this analysis were similar to those in the former study. The primary factor was concerned with the standardized measures of language. Additionally, there were factors that reflected the extent of discourse participation.

The research concerned with the dimensionality of the various aspects of oral communication is quite consistent. One latent trait subsumes vocabulary and sentence use regardless of whether this involves listening or speaking. A second trait reflects speech sound production ability, which is often termed "speech articulation". Finally, a third aspect of communication appears to be concerned with language use in social contexts. This last dimension has received the least attention, and it is possible that this domain contains more than one dimension. These conclusions provided the basis for my proposal of a three-dimensional space containing most of the individual differences in children's communication, shown in Figure 18.1. This conceptualization also provides for three regions of poor performance that might contain different forms of developmental communication disorder. The first region shown on the X axis reflects language and fits well with children described as DLD, and it will be this dimension that we will focus on here. Children with DLD are shown in black. Another dimension reflects poor speech sound ability and maps rather well to the diagnostic notion of developmental speech sound disorder. The third dimension, concerned with pragmatics and social communication, may contain those communication deficits found in children with autism spectrum disorder (ASD) and pragmatic language impairment (PLI; Bishop, 2000; Brook & Bowler, 1992). There has been considerable debate as to whether the communication skills of children with PLI or ASD represent variation in degree or in kind and also whether these children overlap with children who have SLI (Roberts, Rice, & Tager Flusberg, 2004; Tomblin, McGregor, & Bean, 2011; Williams, Botting, & Boucher, 2008). Embedded in this controversy there seems to be general agreement that children with poor language skills often have better social communication skills than they have language skills, whereas those with ASD or PLI can show the opposite pattern, and thus in this regard the idea that the domains of pragmatics and language are at least partially independent is supported. Thus, for the remaining pages, we will be focused on the individual differences in children along the language dimension and in particular on those who have poor language skill.

The evidence that there is a single dimension for language content and form raises some interesting questions as to whether this has implications for the nature of the content of a language intervention program. In one case we can assume that if you push development

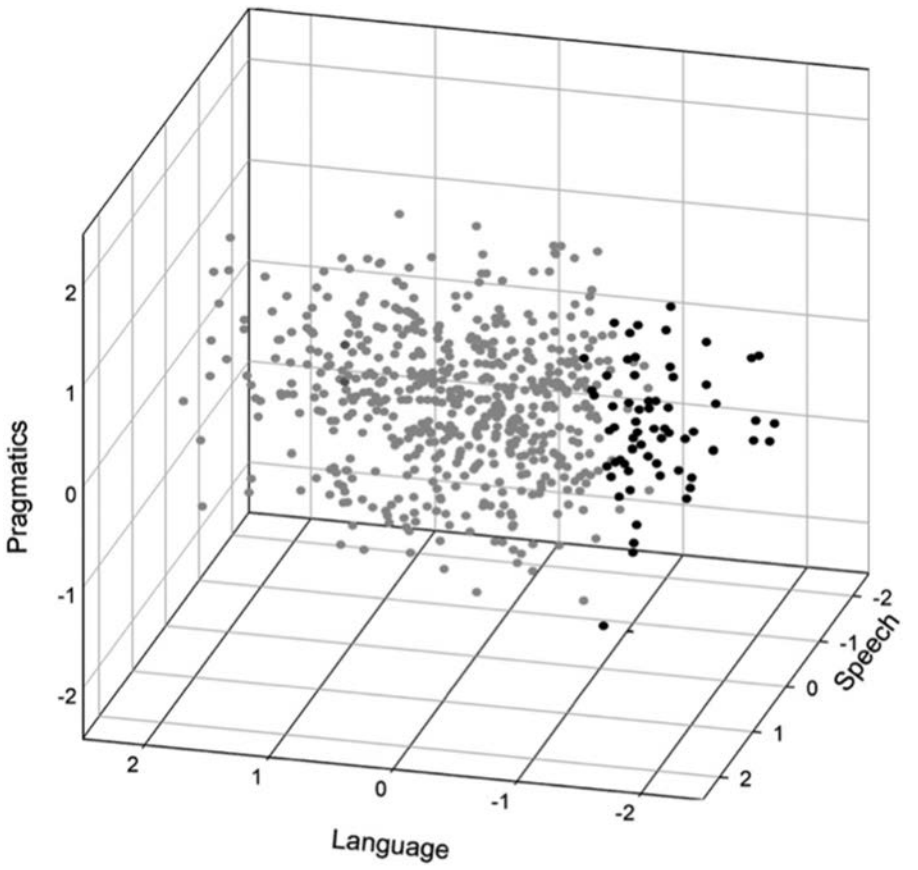



*Figure 18.1* A three-dimensional space containing the major dimensions of communication ability with a trivariate distribution of hypothetical children contained in it. Children with low levels of language ability are shown by the black spheres.

in any area, it will bring the rest along. Alternatively, we can assume that the language skills and knowledge are being learned in a piecemeal fashion. In the former case, planning language intervention would entail the selection of specific targets that are then given high intensity focus with the expectation that this would move the whole system, and thus we can expect considerable generalization from our intervention efforts. In the alternate account, we expect limited generalization since what is learned is more independent, and therefore intervention may require a broad scatter shot exposure to language or alternatively a selection of targets based on utility, accepting that we can't train everything. You can see that the first account assumes that the language representations of children are very abstract and part of an integrated system such as a generative grammar. The second account assumes a less abstract system involving exemplars and constructions that may represent independent or semi-independent entities. If you spend any amount of time studying language science, you will recognize that this issue represents one of the most prominent and hotly debated issues in the field (see Chapter 1, this volume). However, I believe that each of these accounts could allow for a single dimension. If the abstractions are made across the domains of words and grammatical rules, then a single dimension would be

expected. If the system is composed of an aggregate of semi-independent representations (words and constructions), then everything is learned in the same way and the efficiency of the learning system provides a common constraint across the representations. Thus, it is not clear that the evidence of a single dimension provides much guidance with respect to how to select the content of a language intervention program.

## Do children with poor language form a distinct group?

Having established a dimension of individual differences formed by variation in language, we can then ask how the children with poor language differ from those with better abilities. In particular, can we find evidence that there is a natural boundary between these two groups such that these groups represent natural kinds (Ellis, 2001; Quine, 1969)? Natural kinds are thought of as entities that form a class that can be explained and justified based on laws or principles of nature. Natural kinds therefore exist in nature independent of human conceptualization and are discovered by scientific methods found in the natural sciences. One characteristic of objects that form natural kinds is that on certain critical properties, they are more similar to each other than to those things that are not in the class. These properties are the defining characteristics of this class. This feature of natural kinds suggests a clustering of the features.

Several years ago, we performed a cluster analysis on a large sample of children with and without poor language abilities (Tomblin & Zhang, 1999). This analysis was performed on a set of 1929 kindergarten children who had participated in an epidemiologic study and represented children with a very similar profile; the differences among the cluster groups were largely due to different levels of language proficiency. Recently, these data have been reanalyzed, and the same conclusions were reached that within children with normal or poor language abilities, there was no evidence of distinctive clusters of subgroups (Lancaster, 2015). Although this sample was based on a population sample, we had over-sampled children with low levels of language ability. Even with this over-sampling, there was no evidence that the patterns of performance in the children with poor language were different from those of the typically developing children.

Later, we (Tomblin, Zhang, Catts, Ellis Weismer, & Weiss, 2004) addressed this question again in a study of language dimensionality in second-grade children. Recall that we had derived a five-dimensional space comprising language, phonological awareness, nonverbal IQ, and two dimensions reflective of pragmatics. In this analysis, we performed a latent class analysis on these five dimensions. Importantly, the scores we submitted to this analysis were referenced to the child's overall level of performance. Thus, the analysis was concerned with the profile of ability rather than the overall severity. This resulted in two clusters that reflected either relatively high language ability and relatively low pragmatics or the opposite pattern. Importantly, children with DLD were represented in both groups. These results show that there is very little evidence that children with DLD represent a natural kind based on the grounds that they share similar characteristics among themselves and also contrast with other language learners on these features.

In addition to differential similarity of characteristic features, a natural kind is also viewed as being discontinuous relative to other similar kinds. That is, the very nature of kind suggests that the distribution of the members of one kind will be separable from other kinds on some characteristic. This discontinuity of distribution can be tested via Taxometric Analysis. Dollaghan (2004, 2011) used a particular type of Taxometric method (MAMBAC) that empirically reveals discontinuities in the joint distributions of traits that are considered important to some condition. In both studies, Dollaghan examined several language traits in a large sample of children

at two different points in development, and in neither study was she able to find evidence of a distinct subgroup of poor language learners.

At this point, all of the empirical studies that test for some characteristic of poor language have not provided support for the conceptualization of these children as a natural kind of language user/learner based on their language behavior. These data suggest that they seem to occupy the low end of a quantitative trait. We need to be cautious with regard to what conclusions can be reached with these findings. These analyses were focused on measures of language and communication behaviors. It may be that sharp group differences would be found if the range of behaviors had been extended beyond language. More importantly, it is possible that the cognitive and neurobiological mechanisms that serve language development are qualitatively different in these children, but the behavioral result is highly constrained, and therefore there is a common final pathway for individual differences that obscures the presence of a distinctive group of poor learners. At least at the level of language behaviors, it is hard to discern the presence of groups, and instead we see a graded variation in what can be viewed as a latent trait of language ability.

## Markers for DLD

Although the taxometric analyses have not supported the existence of a distinct group of children with DLD, there has been considerable research proposing that there are behavioral markers that may be used to identify these children and set them off from other language learners. The term "marker" seems to have been introduced by Bishop, North, and Donlan (1996) in reference to genetic markers of DLD. Soon afterward Rice (1997) adopted the term and later (2003) suggested that ideal markers should have a bimodal distribution reflective of a distinctive group of learners who had a genetically based impairment in the use of obligatory finite markers. As such, this body of research appears to assume or claim that children with DLD are a distinctive group of language learners and thus could be taken as evidence that DLD represents a distinct taxon of language learners. Because such a marker is proposed to reflect a biologically based etiology, it should be present regardless of the language the child is learning. I will return to the data that test this implication shortly.

Around the same time that Rice was using the term "marker" to connote a distinctive group of language learners, Conti-Ramsden, Botting and Faragher (2001) also employed the term, but may have used the term in a different way. In their work, they were interested in whether there were diagnostic measures that were particularly informative with regard to DLD caseness. That is, they were focused on the clinical utility of markers. This alternate meaning of "marker" could be taken to mean that the measure would be just as sensitive to individual differences among typical language learners as to those differences that span DLD and normal levels: that is, the measure is simply a good measure of individual differences in the dimensional language ability trait noted above. This sense of the term "marker" does not necessarily imply a DLD taxon. However, its existence could be viewed as consistent with a taxonomic account. Thus, often those finding evidence of a clinically useful marker saw this as support for DLD as a taxon. Since the turn of the century, there have been scores of studies examining the viability of markers for DLD (usually termed SLI). These studies have concentrated on three markers: grammatical morphology and more specifically finiteness marking, sentence imitation, and nonword repetition. Often in this literature the authors are unclear as to what they mean by "marker" and thus what the findings of their research tell us about DLD. Below I will examine this literature in an effort to determine whether it supports one or the other of these conceptualizations of the term "marker."

## *Grammar marker*

Perhaps the best known and studied marker of DLD has involved measures of grammatical morphology and in particular inflectional morphology. The interest in the grammatical abilities of children with DLD that set them apart from typically developing (TD) age mates dates back to some of the earliest studies of DLD (Leonard, 1972; Menyuk, 1964). These studies reported several qualitative differences in the grammar of children with DLD when compared with chronological age mates, leading to the term "deviant language", which clearly suggests the notion of a taxon. Soon Morehead and Ingram (1973) argued that normal language development involves qualitative changes over development. Thus, children who are at different points in development can be expected to have different qualitative language characteristics. Given that children with DLD are at an earlier stage of development, we should expect qualitative differences. This perspective introduced the practice of comparing children with DLD with younger children who are at the same level of language development. Evidence for a qualitative difference required that the children with DLD be different from children who are presumably at the same point in development.

The use of younger language-level-matched children (often via mean length of utterance (MLU)) quickly became the standard paradigm over the following decades as various aspects of grammar were studied (see Leonard, 2014, for a thorough review of this literature). Following the lead of Johnston and Schery (1976), the research focused on whether grammatical morphology was an aspect of language that differentiated children with DLD from TD children. This work showed that children with DLD followed the same progression of grammatical morpheme acquisition, but their proficiency with these forms lagged behind expectations based on their MLU, suggesting that this aspect of language was particularly challenging to them and possibly a sign of a qualitative difference. Later, the focus on grammatical morphemes in general narrowed to morphemes marking tense and aspect, which are viewed within some linguistic accounts as being controlled by a grammatical feature of finiteness. This feature of finiteness in English is obligatory in finite clauses, but not in infinitive clauses. Several studies showed that English speaking children with DLD were less likely to mark tense and/or aspect in finite clauses than their MLU-matched mates (Cleave & Rice, 1997; Leonard, Bortolini, Caselli, McGregor, & al, 1992; Leonard, Eyer, Bedore, & Grela, 1997; Oetting & Horohov, 1997; Rice & Wexler, 1996; Rice, Wexler, & Cleave, 1995). I should note here that the rate of tense and aspect provision varied in degree across development among children who were TD as well as among those who were DLD. On average, Rice has shown that 3-year-olds are at 50% and increase to 100% by age 5. Rice has argued that despite this graded quality, the distribution of finiteness in children over the age of 5 appears bimodal, and poor performance on tense marking differentiates children with DLD from those who are TD (Rice, 2004).

Various theories were generated to account for why grammatical morphology is problematic for children with DLD. One class of these theories drew on nativist accounts that these children had defective grammar acquisition systems within a dedicated neurobiological language acquisition module. One prominent example of this type of theory has been the Extended Optional Infinitive (EOI) account by Rice and colleagues, wherein a grammatical feature concerned with obligatory finiteness marking entails a maturational delay in these children (Rice, 2003; Rice et al., 1995). Rice has argued that once this finiteness marker is triggered in the child's grammar, the rate of acquisition in children with DLD is similar to that for typically developing children. An important feature of these maturational accounts is that tense and aspect difficulties should be universal and could be used to identify children who are DLD across languages. In

the past two decades, this prediction has been tested across several languages. In the last 25 years, the grammatical skills of children with DLD, particularly with regard to tense and aspect, have been compared with those of language-matched TD children speaking a number of different languages such as English, Swedish, Italian, and Spanish (Håkansson, 2001; Hamann et al., 2003; Morgan, Restrepo, & Auza, 2009; Rom & Leonard, 1990; Umberta, Cristina, Patricia, & Leonard, 2002). After an extensive review of this literature, Leonard concluded that there is no universal feature of grammar including finiteness that can be used to characterize children with DLD (Leonard, 2014). As a product of his examination of the profiles of grammatical difficulties shown in children with DLD, Leonard has proposed that tense and aspect in English are challenging to children with DLD due to the phonetic obscurity of the grammatical markers (Leonard et al., 1997). A somewhat similar account that emphasizes properties of the input can be found in the informative hypothesis (Rispoli, Hadley, & Holt, 2012). These challenges resulting from the input features of English grammar could then interact with limitations in non-language-specific cognitive systems to lead to their prominence as areas of deficit. This same account can be extended to other features of other languages that each present their own challenges to learning.

It is important to point out here that these accounts do not require that the underlying processes that constrain grammar learning in children with DLD don't also apply to typically developing children. In the case of the maturational account, children with DLD have a delayed onset of a biological triggering of the obligatory finite feature, but the timing of this trigger could easily be graded, leading to variation in proficiency in general. Likewise, Leonard's accounts are based on variations in the sufficiency of general purpose cognitive processing systems, and thus these too could be graded. We can see that the research concerning grammatical morphology for DLD suggests that its prominence as a distinctive marker is likely to vary across development and across languages. In the accounts above, children with DLD are not viewed as incapable of acquiring these inflectional morphemes, but rather seem to be slowed in one way or another.

Although the research concerning tense and aspect does not support the notion that this is likely to be a useful marker for DLD across languages, it has still been considered as a possible clinical marker for English speaking children. In the past 20 years at least 16 studies have addressed this issue. In these studies, measures of tense and aspect were evaluated with regard to their ability to correctly assign children as cases or non-cases, and thus these studies do not seem to be committed to this marker as a taxonomic marker. In fact, unlike the prior research where the contrast was between DLD children and younger TD children selected to be at the same level of language development, this question was tested by comparing tense and aspect use in DLD cases and TD chronological age-matched controls. As Leonard (2014) explains, this comparison is reasonable because clinical decision making is usually based on the child's status relative to chronological age-matched peers. This does, however, alter the question being addressed. In the prior research, the question was whether there were ways in which children with DLD showed disparate language from TD children at the same general ability level – that is, as described by Leonard, whether finiteness represented an extraordinary aspect of language learning for children with DLD. In these studies, concerned with diagnostic accuracy, the question was less demanding and can be interpreted to be concerned with the degree to which the grammatical marker is strongly correlated with the variables that led to the determination of DLD caseness or non-caseness.

In clinical research this association is tested between a candidate clinical measure that generates predicted case and non-case assignments and a well-regarded (gold standard) diagnosis. Clinical utility is reflected by the proportions of individuals correctly assigned to be cases (true

positives) or non-cases (true negatives) as well as incorrectly assigned to be cases (false positives) and non-cases (false negatives). These data form a four-fold table that can be used to generate a variety of statistics, several of which are nonparametric correlations. Two indices frequently used to test for diagnostic accuracy are specificity and sensitivity, where specificity is the proportion of true non-cases, based on the gold standard correctly assigned by the candidate marker, and sensitivity is the proportion of true cases correctly assigned. A closely related measure concerns the degree to which the measure, such as tense, is informative with regard to a person being a case or non-case. This is a Bayesian type of metric that asks how much knowing about finiteness ability improves our ability to determine caseness or non-caseness. These are reported as a likelihood ratio positive (LR+) or the likelihood of being a case given the marker information. LR+ values range from 1 to infinity. A second metric is the likelihood ratio negative, which is the likelihood of being a non-case given the marker information. LR- values range from 1 to infinitesimal. LR+ values lower than 5 are not considered clinically useful, and values greater than 10 are viewed as quite informative. Values of LR- more than .50 are not viewed as clinically informative, and values of less than .1 are highly informative.

The research on diagnostic accuracy has been summarized by Pawlowska (2014). She performed a meta-analysis of 15 studies of the diagnostic accuracy of finiteness markers. Across these studies the LR+ was 5.9, and the LR- was .33. Thus, finiteness was marginally able to predict caseness (LR+ > 5.0) and was modestly good at predicting non-caseness (LR- < .5) Pawlowska also showed that the diagnostic accuracy of finiteness particularly with regard to LR- declined with increasing age in the children. Recently Guo and Schneider (2016) compared the accuracy of group assignment based on finiteness marking in children at either 6 or 8 years of age. This study showed that the finiteness provision rate was able to accurately classify the younger children, but not the older children. These findings are consistent with findings I referred to earlier concerning the growth curve analysis of tense provision rates between 4 and 8 years by children with and without DLD (Rice, Wexler, & Hershberger, 1998). In this study, the typically developing children reached the maximum level of tense use by 5 years of age. Gains in general morphological provision continued to 8 years of age for the DLD children; however, the difference in performance levels diminished substantially, although a group difference remained. In all of these studies, finiteness marking was measured via analyses of spontaneous language samples. Poll and colleagues (Poll, Betz, & Miller, 2010) were able to differentiate between young adults with and without DLD using a grammatical acceptability task involving inflectional morphology; thus, inflectional morphology remains somewhat vulnerable among those with DLD even into adulthood. Importantly, this study also found that other measures of language ability in these adults were more accurate in differentiating individuals with and without DLD, thus underscoring that this is not likely to be a unique or specific marker of DLD.

The results above do support the notion that among English speaking children acquisition of grammatical morphemes and in particular those controlled by finiteness is informative about DLD during the preschool years and early school years. Note that in these studies, since overall language ability was not controlled, we can't claim that this is a unique or particularly good clinical marker, but it seems best for children between 3 and 7. I conclude from this that this developmental dependency reflects a period where finiteness is being mastered by most children, and during this time it stands out as a challenging learning problem. This interpretation of finite marking as a diagnostically sensitive marker in English speaking children is consistent with the literature showing that grammatical markers of DLD across languages will vary depending on the particular language. Leonard has concluded that what serves as a grammatical marker for DLD seems to be that aspect of grammar in that language that is particularly difficult because of the learning challenge presented by this language feature. Thus, what makes for a good marker

of DLD is anything that maximizes individual differences among children at that developmental period in that particular language.

## *Sentence repetition*

Another candidate marker for DLD that has received considerable attention has been sentence imitation or sentence recall. Unlike grammatical morphology, which focuses on a particular aspect of language and measures this in a variety of tasks, sentence imitation holds the task fairly constant and presents the child with a wide range of different sentence forms. In most instances, the task involves providing the child with a spoken sentence, and the child is to repeat back verbatim what is said. The child's performance is scored either at a word or morpheme level or at the whole sentence level of accuracy. The utility of elicited sentence imitation for the study of language abilities in children extends back to the work of Menyuk (1963), Ervin (1964), Rodd and Brain (1971), and Slobin and Welsch (1973). No doubt due to their influence, many of the common language assessment batteries, such as the *Clinical Evaluation of Language Fundamentals* (Semel, Wiig, & Secord, 2004) and the *Test of Oral Language Development* (Newcomer & Hammill, 1997), have incorporated sentence imitation as one measure of sentence usage.

Unlike grammatical markers, the research on sentence imitation appears to have been only concerned with its utility for diagnosis. As such, all the research has involved children with and without DLD who are at the same age. The utility of sentence imitation in the diagnosis of DLD came from an early study searching for indicators of DLD in adults (Tomblin, Freese, & Records, 1992). In this study, we included a sentence imitation task and found this to be a strong predictor of poor language in a sample of young adults with and without DLD. It is noteworthy that this study used a multivariate discriminant analysis and as such included other measures of language. Sentence imitation was found to be the best predictor, but diagnostic accuracy was improved by adding other measures. Later, Conti-Ramsden, Botting, and Faragher (2001) used discriminant analysis to test the degree to which a set of markers (sentence imitation, nonword repetition, past tense marking, and number agreement) discriminated between 11-year-old children with and without DLD. Sentence imitation was found to be the best single predictor of DLD, followed by nonword repetition. The two morphological markers were less sensitive, which might be expected at this age given the earlier findings that morphological skills are not strong markers of DLD in older children. Subsequently, Stokes, Wong, Fletcher, and Leonard (2006) compared the diagnostic accuracy of sentence imitation with another candidate marker – nonword repetition – in Cantonese speaking children and again found sentence imitation to be accurate in classifying children with DLD whereas nonword repetition was not an informative marker. These findings were subsequently replicated in English speaking children (Archibald & Joanisse, 2009) and English speaking adults (Poll et al., 2010) and French speakers (Leclercq, Quémart, Magis, & Maillart, 2014). The evidence for sentence imitation as an informative measure of DLD was supported by the meta-analysis of candidate markers by Pawlowska (2014). Similar to the infinitive marker discussed earlier, this analysis showed that poor sentence imitation performance was a good sign of DLD, but good performance was not necessarily evidence of an absence of DLD. Thus, sentence imitation has emerged as a robust measurement tool for the diagnosis of DLD. Unlike grammatical markers, it seems to perform well across a wide age range. Thus, as a diagnostic tool, this task has good utility. I should add that this utility may be limited to decisions about diagnosis (i.e. caseness) in general. Concerns have been voiced about the variability in correspondence of children's provision of specific grammatical forms in spontaneous speech and in imitation (Fujiki & Brinton, 1987; Prutting & Connolly, 1976), and therefore the utility of sentence imitation for the selection of treatment targets remains questionable.

Within the context of this discussion we need to ask whether sentence imitation is reflective of an underlying deficit in language ability that qualitatively differentiates children with DLD from TD children. There have been two general explanations provided to answer this question. Since the task involves presenting a stimulus in the form of a string of words, it can be hypothesized that this is a type of working memory task. A frequently cited example of the working memory account is that of Alloway, Gathercole, Willis, and Adams (2004). In this account sentence recall draws on the episodic buffer that is a part of Baddeley's working memory. Alloway proposes that sentence recall draws on the capacity of the episodic buffer to integrate representations from memory subsystems. In this vein, Poll argued that the performance differences among young adults with and without DLD were due primarily to working memory constraints (Poll, Miller, & van Hell, 2016).

In contrast with the notion that sentence imitation is reflective of a working memory deficit is the claim that performance on a sentence repetition task is reflective of the child's language knowledge. This account dates at least as far back as Ervin's observation that children cannot imitate sentences they cannot produce (Ervin, 1964). Later Rodd and Brain (Rodd & Brain, 1971) proposed that sentence imitation was reflective of the child's grammatical competence. Potter and Lombardi (1990) subsequently presented evidence that sentence imitation involved the same processes used for natural listening and speaking. They proposed that upon hearing the sentence to be imitated, the individual abstracts a semantic representation via comprehension and then from this semantic representation regenerates the sentence. Thus, according to this view, sentence imitation captures the processes of comprehension, representation, and sentence formulation. Support for this account has been provided in studies showing that errors in imitated sentences conform to the child's grammatical performance in spontaneous language (Riches, Loucas, Baird, Charman, & Simonoff, 2010) and that accurate imitation is more likely for sentences that can be understood by the child (Komeili & Marshall, 2013). Several investigators have conducted studies that provide support for this type of account by showing that performance on sentence imitation is strongly correlated with other measures of language (Klem et al., 2014). At this point, we need to consider that the two accounts of sentence imitation (working memory vs language knowledge) are not necessary opposed to each other. MacDonald and Christiansen (2002) have argued that the constructs of working memory and language representations are not distinct but instead involve the same cognitive systems. Within a connectionist perspective, representations are held in distributed neural networks, and working memory tasks involve activation of these representations. Thus, if the representations in the network are well established, working memory capacity is improved.

We can argue then that sentence imitation is likely to incorporate many of the processes involved in language use, and the language content of the sentences draws upon the child's knowledge or representations of this content. Because the content can be varied, this allows the items in the test to sample across a wide range of ability. From this perspective sentence imitation may provide a measure of language ability that is discriminative across a wide ability spectrum and therefore is good at revealing individual differences, and in this regard it is a good marker of language ability in general rather than tapping the unique language features of DLD.

## *Phonological memory*

As we saw above, short-term memory or working memory has been hypothesized as the reason children with DLD struggle with language learning. Limitations in short-term memory span for retention of strings of words of increasing length among children with DLD have been described for years (Aten & Davis, 1968; Sininger, Klatzky, & Kirchner, 1989). Recent research

has examined short-term memory within a theoretical framework for working memory by Baddeley (Baddeley, 1992, 2003). A key component of this working memory model is a short-term phonological memory system. Within this account, phonological memory has a capacity to hold novel word forms that is central in learning novel words (Gathercole & Baddeley, 1989). This capacity varied across children and was an important influence on individual differences in vocabulary learning across children. The capacity of this memory system has been measured via a task involving repetition of nonwords (NWR) of increasing syllable length. Nonwords were employed to minimize the influence of linguistic representation in long-term memory on nonword recall. Because of its potential role as a causal mechanism in language learning, nonword repetition and phonological memory quickly became a candidate as a cause and marker of DLD (Gathercole & Baddeley, 1990). Graf Estes, Evans, and Else-Quest (2007) reviewed 25 data sets from 15 studies examining nonword repetition in children with DLD in comparison with either chronological age-matched or in some cases language-matched children. These studies typically reported average performance levels rather than diagnostic accuracy, and therefore Graf Estes et al. summarized the results in terms of Cohen's d. Across these studies Graf Estes et al. found that the average overall effect size was $d = 1.27$. Soon after this review, Coady and Evans (2008, p. 1) noted that nonword repetition was "a powerful tool that can be used to identify children with language impairments". I should note that the majority of these studies involved a contrast of age-matched TD children with the DLD children. In a few cases, studies summarized in the Graf Estes et al. review included language-matched children. An examination of these differences in matching shows a substantially lower effect size for most of the studies employing language-matched comparison groups. This suggests that nonword repetition may be associated with the language ability level of the children rather than a marker of a qualitative feature of DLD. Direct evidence against nonword repetition as serving as a reflection of a distinct taxon can be found in the taxonomic study of Dollaghan (2011), where nonword repetition was used in a taxonomic analysis and no evidence of a separate group of children was found.

We can see that although the research above has often assumed nonword repetition as a measure of the capacity of the phonological memory system, we need to consider an alternative. Several researchers have argued that repetition of nonwords is largely reflective of the child's language knowledge. Thus, rather than being a cause of individual differences in vocabulary learning, it was a reflection of the number of words the child had learned. This was raised by Snowling and colleagues (1991) soon after Gathercole and Baddeley's early paper (Gathercole & Baddeley, 1990). Snowling and colleagues (1991) and Dollaghan and Campbell (1998) also noted that nonwords used in this task often contained real words within them, and this allowed for language ability to influence nonword repetition accuracy. Munson (2001) presented evidence that the frequency of phonological patterns within nonwords influenced performance. Later, Munson and colleagues (2005) demonstrated that this effect of phonological pattern frequency was driven by the child's vocabulary size. These two alternative accounts of the relationship between nonword repetition and vocabulary were examined in depth by Gupta and Tisdale (2009), wherein a computational model was tested. Gupta and Tisdale concluded that word learning was dependent on a functional phonological short-term memory system that retain phonological sequence information regarding a novel word. They also found that this functional memory system interacted with long-term memory, and thus lexical knowledge influenced nonword repetition accuracy. Gupta and Tisdale concluded that the two positions (memory capacity or language knowledge) were not in opposition. We need to appreciate, however, that the phonological memory system in this model was purposefully labeled as a functional system. In this sense, there was no short-term phonological memory system with a fixed capacity built into the model. Instead, this function was emergent from the recurrent interplay between

hidden units and context units. This suggests that nonword repetition, like sentence repetition, may be a reflection of a number of important systems involved in language use and as such is a measure of language ability rather than an independent precursor to language that is impaired in children with DLD.

### *Summary of markers*

I asked at the beginning of this chapter whether the literature on markers for DLD could be viewed as suggesting that DLD could be viewed as a taxon, that is, a natural class, or, alternatively, whether this literature should be interpreted to mean that these markers were good at differentiating language abilities among children and thus also children with poor language abilities from those with better language abilities. For each of the candidate markers, a simple unifying interpretation of the findings of research is that these measures do not provide evidence that children with DLD form a distinct taxon. Instead, if these measures are to be viewed as markers, they should be thought of as simply being good measures of the general language trait that has been found in studies of the dimensionality of language. In fact, both sentence imitation and measures of grammatical morphology were included in the factor analysis we performed for children in second grade (Tomblin et al., 2014). In this case, the first factor was clearly a general language factor where measures of vocabulary and sentence use were highly loaded. One measure, the Exploratory Test of Grammar, was a grammatical morphology task based on a Berko type close task (Berry & Talbott, 1966) which loaded 0.72, and another was a sentence imitation task (Clinical Evaluation of Language Fundamentals III (CELF-III) Recalling Sentences subtest) which loaded at 0.82. Collectively, I believe there is very little convincing evidence that children with DLD qualitatively differ from other children other than being less adept at acquiring language. There are no obvious natural classes of language learners, nor are there markers that single these children out.

## What do we mean by DLD?

If DLD does not represent a natural type or class of language learners, we are left with the problem of deciding what it is that we mean by DLD, how to assign this term to children, and why we bother having such a term. A number of years ago, I came across a controversy in the medical literature with regard to the nature of constructs of disease and illness that has been helpful to me. At the center of this controversy was whether health and ill health are defined by the causes of the conditions or are socially informed constructs. The former account views health and ill health as defined by the status of natural causal systems. When one of these systems is defective or damaged, the person enters into a state of ill health. Determining if a person is ill entails determining the cause, which is the broken system. In this regard, illness is an inherent property of the person and is discovered via diagnosis. In the alternate position, ill health is determined by the values of a particular society. This is sometimes called "normativism" in reference to social norms. These health states are not natural classes, but rather are arbitrary and fluid. Furthermore, health and ill health are not inherent properties of the person but rather are assigned states. I have argued that the latter perspective seems to be a good framework for thinking about DLD (Tomblin, 2006; Tomblin, 2014; Tomblin & Christiansen, 2010). In many respects, this viewpoint makes our thinking about DLD more difficult. We can't leave it to nature to sort out who does or doesn't have DLD, but in fact we need to take comfort that this is true for all health conditions.

Within the normativist position, I believe that we can say that DLD represents a statement about the likelihood that a child will face penalties in life as a result of his or her language ability. It is not a statement about why the child has poor language abilities, but rather a prediction about risk for undesirable life outcomes. We now have very strong evidence that poor language abilities at the time of school entry are strongly associated with poor reading outcomes (Bishop & Adams, 1990; Catts, Bridges, Little, & Tomblin, 2008; Nation, Clarke, Marshall, & Durand, 2004), social difficulties (Conti-Ramsden & Botting, 2004; Durkin & Conti-Ramsden, 2007; Fujiki, Brinton, Isaacson, & Summers, 2001), and depressed long-term educational and occupational outcomes. It is clear that poor language abilities are likely to have increasing effects on these outcomes as society moves more toward work that requires knowledge and communication skills rather than physical labor. Thus, there is little argument that poor language abilities represent a risk to overall well-being, thus warranting clinical concern.

This perspective then emphasizes that the term "DLD" represents a statement about a child's risk for worrisome outcomes, and its function is to aid in directing clinical actions to reduce these outcomes. Importantly, because we no longer see DLD as a discrete category, this risk for troubling outcomes is graded depending on the degree of depressed language skills. Therefore, for practical purposes we find ourselves needing to distinguish these children from others who are at less risk. Unfortunately, there are no sharp lines for these risk functions to allow us to rationally determine who to treat and who to exclude, and therefore clinical decision making regarding caseness must be done in an inherently ambiguous context. This process of clinical decision making is not unique to DLD but is necessitated in health services for two reasons. In many medical treatments, there are both benefits and risks to well-being. We don't want to subject someone to treatment who in fact is not ill and in so doing possibly jeopardize their well-being via the treatment. This condition doesn't seem to apply to treatments for DLD. The treatments are generally aimed at promotion of learning and in fact are likely to be helpful to most children. Even children at very minimal risk for poor outcomes are likely to benefit from a program that promotes better language abilities. Thus, the main issue in our clinical decision making has to do with cost. Most of these clinical services for DLD require funding, and thus the issue is a cost-benefit decision and this does hold for DLD. The cost in this case has to do with the cost of treatment provision but also the cost to the child and society if the risk is realized due to either no treatment or ineffective treatment. When viewed in this way, we would say that the notion of DLD applies to all children where the cost to them and society from their persisting language status exceeds the cost of efforts to reduce these penalties. At this point in time we can see that what we are lacking is the research base to establish what these costs and penalties are. Much of our research, including my own, has been focused on the natural science explanations of DLD; however, this research will not provide the evidence we need to tell us where in the distribution of children's language abilities the penalties of DLD outweigh the costs of treatment. This kind of research is often done via social science research and in particular economic work. The natural science focused inquiry into factors that drive individual differences remains important as this should help us understand how best to intervene, but the economic research should provide the evidence as to whom we should treat.

## Clinical intervention for DLD

The focus of this chapter has been on the nature of DLD and in particular whether these children represent a distinctively different kind of language learner. My conclusions are that the weight of evidence points to a view that these children are like other, more adept learners.

That is, they go about language learning in a similar manner, but are less adept. This conclusion would imply that clinical intervention would entail programs that provide the child with a language environment that is based on what we have come to know or at least believe promotes good language growth in children in general. In fact, current clinical practice largely reflects this. Recently, I was a part of a committee that authored a report by the U.S. National Academy of Sciences (National Academies of Sciences, Engineering, and Medicine, 2016). In this report, clinical intervention is described for children at three different phases of development. The first phase is for children in the early childhood period from birth to 3 years of age. Intervention during this period is focused on enhancing the quality and quantity of language input provided to the child by parents and caregivers. The key features of this involve helping parents learn to employ responsive communication styles throughout the day. This type of communication was identified in early research on typical parent-child interactions (Cross, 1978; Goldfield, 1987; Landry, Smith, & Swank, 2006). By focusing on a family based approach, these clinical efforts acknowledge that early and frequent language input that follows the child's activities and communication can promote better language growth in children who are DLD. Clinical treatment for children in the preschool years (3 years to school entry) often shifts from home based to a preschool or treatment center based delivery system wherein teachers and clinicians provide language intervention programs. Even in this setting, the intervention principles continue to emphasize elevated amounts of language input and methods of language interaction with the children such that the teacher takes what the child is saying and then expands on them, modeling utterances that contain form and content that is related to the child's utterances. Thus, throughout the preschool years, language intervention is often consistent with the premise that these children are going about language learning in the same way as the typical child, and thus the treatment is focused on optimizing the learning opportunities for the child. To some degree, this perspective changes as these children with DLD enter school. At this point, intervention is targeted at language content and skills that are central to the school curriculum. Furthermore, treatment methods are likely to involve more explicit instruction and have more metalinguistic focus. Even in this more remedial environment, the instructional pedagogy employs the same principles as those used for instruction with typical learners. Thus, it seems that our current practices of intervention are consistent with the evidence that these children are not qualitatively different learners. We can see from this that a view of children with DLD that emphasizes their similarity to other typical children allows us to employ all of the theory that addresses the processes of development and learning. All the body of work in developmental psychology can apply to these children, and the insights from research on DLD should also apply and inform thinking in developmental psychology.

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# 19

# SPEECH SOUND DISORDERS IN CHILDREN

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## Definition of speech sound disorders

Children vocalize at birth and these vocalizations are gradually shaped into speech sounds that enable intelligible speech. Children's speech acquisition involves perception, storage, and discrimination of the sound information of speech, and the production of sound combinations to form intelligible speech. The focus of this chapter is children whose speech perception, storage, discrimination, and/or speech production are not developing as expected for their age. The definition of speech sound disorders (SSD) has been revised a number of times over the years. The International Expert Panel on Multilingual Children's Speech (2012) defined SSD as "any combination of difficulties with perception, articulation/motor production, and/or phonological representation of speech segments (consonants and vowels), phonotactics (syllable and word shapes), and prosody (lexical and grammatical tones, rhythm, stress, and intonation) that may impact speech intelligibility and acceptability" (p. 1). This chapter will describe SSD of both known and unknown origins in line with the International Expert Panel definition, where SSD is "used as an umbrella term for the full range of speech sound difficulties of both known (e.g., Down syndrome, cleft lip and palate) and presently unknown origin" (p. 1). However, it is acknowledged that other definitions of SSD only include children whose speech difficulties are "not attributable to congenital or acquired conditions" (American Psychiatric Association, 2013, p. 44).

Five main subcategories of SSD have been described and will be discussed throughout this chapter: 1. phonological impairment, 2. inconsistent phonological disorder, 3. articulation impairment, 4. childhood apraxia of speech, and 5. childhood dysarthria (McLeod & Baker, 2017). Children with a phonological impairment demonstrate a cognitive-linguistic difficulty. Some have delayed phonological development where the developmental error patterns of younger children continue beyond a developmentally appropriate age, whereas others have atypical phonological development where error patterns are present that do not typically occur as part of speech development. These errors are not appropriate at any age (Dodd, 2014). Children with inconsistent phonological disorder demonstrate inconsistent errors when saying the same word across multiple trials due to difficulty with phonological planning in the absence of any accompanying oromotor or oromuscular difficulties (Dodd, 2013, 2014). Children with articulation impairment demonstrate a consistent distorted or substituted phoneme error (most

commonly on sibilant fricatives [e.g., a lateral fricative instead of /s/ in *sing*] and rhotic consonants [e.g., a [w] instead of /ɹ/ in *run*]) across all phonetic contexts and all elicitation tasks. Children with childhood apraxia of speech may demonstrate a variety of errors including errors that are inconsistent, represent poor lexical stress accuracy, and highlight syllable segregation due to poor motor planning and/or programming of motor speech sequences (ASHA, 2007; Murray, McCabe, Heard, & Ballard, 2015). Children with childhood dysarthria demonstrate difficulty producing accurate motor plans and controlling speech production due to an underlying neuropathophysiology (Duffy, 2013). Children with dysarthria may present with oromuscular weakness or incoordination and impaired muscle tone. The challenge in the assessment of children with SSD is to determine the underlying cause for children's speech difficulty (if possible) and make the correct diagnosis to describe the nature of their errors. This challenge is amplified by understanding that children with SSD are heterogeneous and may present with more than one category of SSD (i.e., a child may present with a phonological impairment and an articulation impairment). The prevalence of co-occurring SSD is currently unknown. Correct diagnosis is important to ensure children are provided with the appropriate intervention to support their speech sound development.

Additionally, children may be difficult to understand but not meet the criteria for SSD. Speech difference typically occurs due to dialectical variation between the child and their communication partners. For example, African American English is a distinct dialect of American English. Although much of the phonology between African American English and General American English is common, some characteristics are not common between these dialects. Thus, children who speak African American English as their home dialect may erroneously be diagnosed with a phonological impairment within an environment where General American English is dominant (Velleman & Pearson, 2010).

## Prevalence and incidence of SSD

Communication disorder/disability is highly prevalent in early childhood (Law, Boyle, Harris, Harkness, & Nye, 2000). In childhood, it can be challenging to identify the prevalence of SSD in isolation, particularly when SSD and developmental language disorder frequently co-occur. For example, Law and colleagues (2000) conducted a systematic review of 20 studies exploring the prevalence of speech and/or language delay in children. The systematic review identified that 2.3% to 6.7% of children aged between 2;0 and 5;0 may present with speech and/or language disorder, 2.3% to 24.6% of children aged between 5;0 and 7;0 may present with SSD only (described as "speech delay", p. 169), and 2.0% to 19.0% of children aged between 2;0 and 7;0 may present with language disorder only (Law et al., 2000). More recent studies suggest that SSD may range anywhere from 1.1% (McKinnon, McLeod, & Reilly, 2007) to 18.0% (Roulstone, Miller, Wren, & Peters, 2009) in childhood. The challenge in determining clear prevalence data lies in the varying definitions of SSD (and other developmental communication disorders, such as developmental language disorder, that may include children who fall within the scope of SSD as described in this chapter), sampling methods, and standardization guidelines.

There are large numbers of children with SSD on the caseloads of speech-language pathologists across the world. A study of school-based speech-language pathology caseloads across 37 US states indicated that more than half of children receiving services during Kindergarten–grade 3 (55.8%) and grades 4–6 (51.7%) had goals to develop speech production skills (Mullen & Schooling, 2010). In the Netherlands, 90% of surveyed speech-language pathologists reported they had children with SSD on their caseloads (Priester, Post, & Goorhuis-Brouwer, 2009). In Australia, children with SSD represent a large proportion of speech-language pathologists'

caseloads (McLeod & Baker, 2014), with one investigation identifying that children with SSD were present on the caseloads of 93.1% of sampled speech-language pathologists (Westerveld & Claessen, 2014). In Portugal, speech-language pathologists reported their caseloads contained fewer children with childhood apraxia of speech than children with articulation or phonological disorders (Oliveira, Lousada, & Jesus, 2015). In the United Kingdom, Broomfield and Dodd (2004) identified that 29.1% of children referred to a single service were identified to have "primary speech disability" (p. 141). Of the 320 children who were identified to have SSD, 57.5% presented with a phonological delay, 20.6% presented with "deviant phonological disorder" (p. 141) (defined as the presence of atypical phonological errors), 9.4% had an inconsistent phonological disorder, and 12.5% had an articulation disorder (Broomfield & Dodd, 2004).

## Causes of SSD

Children may have SSD caused by known or unknown origins. Genetic bases, hearing loss, craniofacial anomalies, motor impairments, autism spectrum disorder, and acquired brain injury can contribute to SSD of known origin. Despite these known causes of SSD, the cause of SSD remains unknown for the majority of children with SSD who do not present with any of these known difficulties (Shriberg et al., 2005). It has long been thought that there is a genetic basis for SSD, particularly because the majority of children with SSD are males, and some known speech difficulties arise from genetically linked conditions (e.g., genetic syndromes, cognitive/intellectual impairments, hearing loss). See also Chapter 3 (this volume) for further discussion about the genetic factors in language acquisition. A summary of genetics research by Morgan (2013) indicated that speech difficulties may be linked to five chromosomes: chromosome 1 (Miscimarra et al., 2007), chromosome 3 (Stein et al., 2004) and 3p14 (Horn et al., 2010; Pariani, Spencer, Graham, & Rimoin, 2009; Vernes et al., 2008), chromosome 6p (Smith, Pennington, Boada, & Shriberg, 2005), chromosome 7 (Lai, Fisher, Hurst, Vargha-Khadem, & Monaco, 2001), and chromosome 15q (Smith et al., 2005). The involvement of different genetic abnormalities will often present as complex clinical syndromes. SSD may be a part of the clinical presentation of children with many genetic syndromes, including Down syndrome (Kent & Vorperian, 2013; Sokol & Fey, 2013), Velocardiofacial syndrome (22q11.2 deletion syndrome) (Mills, Gosling, & Sell, 2006), Fragile X syndrome (Barnes et al., 2009), Cri du chat syndrome (Kristoffersen, 2008; Kristoffersen, Garmann, & Simonsen, 2014), Rett syndrome (Woodyatt & Ozanne, 1992), and Treacher Collins syndrome (Vallino, Peterson-Falzone, & Napoli, 2006). Children with a diagnosis of a complex syndrome, similar to those mentioned above, may also present with a cognitive/intellectual impairment that could impact their ability to produce speech sounds correctly. For example, children with Down syndrome may present with SSD due to reduced oromotor functioning, phonological impairment, and/or intellectual challenges that impact communication (Kent & Vorperian, 2013).

Hearing loss, regardless of the cause for the loss, is considered to be a large factor in the disruption of speech sound development in children. Chapter 20 (this volume) provides a comprehensive overview of hearing loss and the language skills of children with hearing loss. Here, we discuss the impact of hearing loss on speech sound development in children. Hearing loss may be due to conductive factors that impact the transmission of an auditory sound wave to a mechanical vibration within the external and middle ear, sensorineural factors that impact the transmission of a mechanical vibration to a neural impulse at the level of the cochlear and auditory nerve, or a combination of these two primary factors. Hearing loss can also be identified at the cognitive level of auditory processing whereby children have difficulty interpreting an auditory stimulus (often called a central auditory processing disorder) (Rance et al.,

2007; Rappaport & Provencal, 2002). Although hearing loss may disrupt children's speech sound development, the presence of a hearing loss does not equate with SSD. A number of factors may impact the development of speech in children with hearing loss, including the age of diagnosis, age of amplification, and type of amplification device (Crowe & McLeod, 2014). There may be some impact of otitis media with effusion (OME) that puts children at risk of SSD. OME is thought to cause inconsistent, intermittently damped auditory input due to the effusion of the middle ear. This damping of the auditory input can impact children's perception of speech. However, debate continues over the presence and magnitude of a link between OME and SSD (Roberts, Rosenfeld, & Zeisel, 2004). Hearing loss may be a factor in children's inability to perceive or process speech sound information, but motor impairments may be a factor in reducing children's ability to produce the sounds required for speech production.

Children with craniofacial anomalies (e.g., cleft palate ± cleft lip) are at specific risk of SSD and will often present with errors that are not common in the speech of children without structural oral inadequacies. Children with craniofacial anomalies may present with different compensatory (active) and/or obligatory (passive) cleft speech characteristics depending on the impact of their specific craniofacial condition (Harding & Grunwell, 1998). That is, they may present with compensatory (active) cleft speech characteristics, which are atypical phonological patterns such as backing to velar, and glottal stop substitution. They may also present with obligatory (passive) cleft speech characteristics including hypernasality, audible nasal air emission and/or nasal turbulence, and weak pressure production of high-pressure consonants (Chapman, Hardin-Jones, & Halter, 2003; Cronin & McLeod, 2019; Scherer, Williams, & Proctor-Williams, 2008).

Finally, motor impairments, autism spectrum disorder, and acquired brain injury may also be associated with SSD. Common motor impairments in children include cerebral palsy, muscular dystrophy, and various syndromes. These conditions may affect the strength and/or muscle tone of children's oromusculature as well as children's ability to manipulate their oromusculature in a coordinated manner. Autism spectrum disorder (ASD) may also impact children's speech sound development, and some children with ASD may present with SSD (Cleland, Gibbon, Peppé, O'Hare, & Rutherford, 2010; Rapin, Dunn, Allen, Stevens, & Fein, 2009). In addition to developmental conditions that may cause SSD, it is also possible for children to acquire SSD in certain circumstances. For example, children may acquire SSD following traumatic brain injury, with young children who incurred their brain injury before the establishment of consonant acquisition at greatest risk (Campbell et al., 2013).

## Risk and protective factors

Although the cause of SSD remains unknown for many children, a number of research studies have been conducted across the world to examine possible risk and protective factors. Risk and protective factors, in the context of identifying children at risk of SSD, may be child factors, family factors, or external factors.

One of the most documented risk factors for SSD is child sex, with males at greater risk of SSD than females (Campbell et al., 2003; Felsenfeld, McGue, & Broen, 1995; Harrison & McLeod, 2010; Law, Boyle, Harris, Harkness, & Nye, 1998; Lewis, Ekelman, & Aram, 1989; Tomblin, Hardy, & Hein, 1991). Positive family history of speech, language, or literacy difficulties is also a risk factor for SSD that has been identified across a number of studies (i.e., Campbell et al., 2003; Felsenfeld et al., 1995; Fox, Dodd, & Howard, 2002; Lewis et al., 1989; Shriberg & Kwiatkowski, 1994).

Low maternal education has been identified as a risk factor for SSD in Hong Kong (SAR China) (To, Cheung, & McLeod, 2013), Finland (Yliherva, Olsén, Mäki-Torkko, Koiranen, &

Järvelin, 2001), Germany (Fox et al., 2002), Viet Nam (Phạm & McLeod, 2018), and the United States (Campbell et al., 2003). Similarly, a study in Germany identified that both mothers' and fathers' level of education could be a risk factor for SSD (Weindrich, Jennen-Steinmetz, Laucht, Esser, & Schmidt, 2000). However, the effect was not consistently replicated when paternal education was considered in China (To et al., 2013).

A factor that does not put children at risk of SSD is bilingual or multilingual language use (Hambly, Wren, McLeod, & Roulstone, 2013; Harrison & McLeod, 2010; McLeod, Harrison, Whiteford, & Walker, 2016). Although some children may show a slower rate of speech acquisition when learning two or more languages, other children may show a more rapid rate of speech acquisition compared to monolingual language learners (Goldstein & Bunta, 2012). While some multilingual children can have SSD, the prevalence is similar in the monolingual population (Winter, 2001), and speaking more than one language is not the cause.

Some risk and protective factors for SSD are confirmed in some studies, and not in others. The contribution of children's pre- and post-natal factors to risk of SSD is unclear. A challenging birth (Fox et al., 2002) and low birth weight (D'Odorico, Majorano, Fasolo, Salerni, & Suttora, 2011) have been identified as possible risk factors by some researchers, but these accounts were not confirmed by others (i.e., Harrison & McLeod, 2010; Tomblin et al., 1991). Similarly, although hearing loss is frequently described as a known risk factor (e.g., Campbell et al., 2003; Harrison & McLeod, 2010; Paradise et al., 2001), the contribution of hearing loss due to OME is not a clearly defined risk factor (Roberts et al., 2004). Some evidence indicates children with low socioeconomic status are not at greater risk of SSD (e.g., Dodd, Holm, Hua, & Crosbie, 2003; Smit, Hand, Freilinger, Bernthal, & Bird, 1990); whereas other evidence suggests they are at greater risk (Templin, 1957; To et al., 2013). Excessive bottle use (Fox et al., 2002), reduced time being breastfed (Tomblin, Smith, & Zhang, 1997), and extended use of a pacifier (Barbosa et al., 2009) have all been identified as risk factors for SSD. In contrast, Shotts, McDaniel, and Neeley (2008) did not find that extended pacifier use put children at risk of SSD. Similarly, Baker, Masso, McLeod, and Wren (2018) found no association between children with phonological impairment and oral sucking habits (use of pacifiers, thumb sucking, breastfeeding, and/or bottle use for more than 12 months).

## Co-occurrence with other disorders

SSD frequently co-occurs with other communication difficulties including language disorder, literacy difficulties, stuttering, and voice disorders. One of the most frequently co-occurring disorders with SSD is delayed or disordered language development that may present as early as the first-word stage of language development (Roulstone, Loader, Northstone, Beveridge, & the ALSPAC team, 2002). This is due, in part, to the relationship between speech and language development in the early years (Stoel-Gammon, 2011). Expressive language difficulties may present concomitantly in up to 50%–70% of children with SSD (Shriberg & Kwiatkowski, 1994), but the identification of those children with a concomitant SSD and language impairment can be challenging. Children with co-occurring SSD and language impairment may make frequent deletion errors, particularly of unstressed syllables (Macrae & Tyler, 2014). Macrae and Tyler (2014) found that children with SSD only (without the compounding effect of language difficulties) presented with more distortion errors than their peers with SSD and language difficulties, but the frequency of substitution errors were comparable between the groups.

Literacy difficulties also frequently co-occur with SSD since speech, phonological awareness, reading, and spelling skills are associated. Some children with SSD may find learning how to read and write particularly challenging (Anthony et al., 2011; Foy & Mann, 2012; Larrivee &

Catts, 1999). Although debate continues about the factors that may put children with SSD at risk of literacy difficulties, there is evidence to suggest that children who continue to present with SSD when they start learning to read may be at greater risk of difficulty when compared to children whose SSD appears to have resolved (Nathan, Stackhouse, Goulandris, & Snowling, 2004). Other factors that may impact children's literacy development are their underlying phonological processing skills (Anthony et al., 2011) and phonological awareness (Preston & Edwards, 2010). There is growing evidence to suggest that children with SSD who present with childhood apraxia of speech (McNeill, Gillon, & Dodd, 2009), atypical speech sound errors (Preston & Edwards, 2010; Rvachew, Chiang, & Evans, 2007), or concomitant language impairment (Lewis, Freebairn, & Taylor, 2002; Preston & Edwards, 2010) may find phonological awareness tasks particularly challenging.

Not all children with SSD have oromotor difficulties. Some have impaired oromuscular structure (i.e., cleft lip and/or palate) and function (i.e., low muscle tone) as possible causes for SSD. In addition, children with motor speech disorders and difficulty completing the motor planning required for speech may also have difficulty completing non-speech oromotor tasks. Approximately one third of English-speaking children with SSD (McCabe, Rosenthal, & McLeod, 1998) and one fifth of German-speaking children with SSD (Fox, 2000) were found to have reduced voluntary oromotor movements.

Although SSD is often considered to be most commonly associated with concomitant language, literacy, and oromotor difficulties, the co-occurrence of SSD and stuttering is also reasonably well documented. Nippold (2002) suggested that between 30% and 40% of children who stutter may also present with SSD. Reports of the co-occurrence of different types of SSD with stuttering have varied, with one study suggesting that articulation disorders are more common (33.5%) compared to phonological disorders (12.7%) (Blood, Ridenour, Qualls, & Hammer, 2003) and another suggesting that phonological disorders were present in 32% of children who stuttered and concomitant SSD and language impairment was present in 33% (Arndt & Healey, 2001). In addition to areas of impairment that clearly relate to SSD in childhood, there is some evidence to suggest that SSD and voice difficulties (i.e., Warr-Leeper, McShea, & Leeper, 1979) can co-occur although the relationship is less well established.

## Natural history of SSD

Studies of natural history examine the progression of a disease (or, in this case, a disorder) when no intervention or support is provided to remediate the condition. The challenge when considering the natural history of children with SSD is that typically long-term studies of children with SSD include an investigation of a particular intervention. Only a few studies have examined the natural history of SSD (Bralley & Stoudt, 1977; Felsenfeld, Broen, & McGue, 1992; Renfrew & Geary, 1973; Roulstone, Peters, Glogowska, & Enderby, 2003; Roulstone et al., 2009). Although some children may improve their speech accuracy over time after a brief period of delay in early childhood, this is not the case for all children with SSD (Gruber, 1999). One study, conducted with German-speaking children, included children with phonological impairment that was characterized by either consistent errors that were atypical for development (consistent deviant group) or consistent errors that were typical of younger children's speech development (phonological delay group). Two thirds of children identified to have a consistent deviant phonological impairment did not spontaneously improve over time, whereas two thirds of children identified to have delayed phonological development did spontaneously improve (Fox & Brodbeck, 2011). A similar result was reported in a small number of Putonghua-speaking children (Zhu, 2002). There is some support for a watchful waiting approach to children with SSD, particularly when

they present with few risk factors and no concomitant difficulties (Roulstone et al., 2003); however, researchers also advocate the importance of listening to parents' concern.

For those children who do not spontaneously recover, SSD can have lasting impacts on their speech skills well into the primary school years. One descriptive measure of children's speech accuracy is Shriberg's (1993) descriptions of early-8 /m, b, j, n, w, d, p, h/, middle-8 /t, ŋ, k, g, f, v, ʤ, ʧ/, and late-8 consonants /ʒ, ʃ, θ, ð, s, z, l, ɹ/. These consonant groupings were determined based on the accuracy of consonants produced by a sample of 64 children with SSD aged 3–6 years where the early-8 consonants were produced correctly 75% of the time by 90% of the children, middle-8 consonants were produced correctly between 25% and 75% of the time, and late-8 consonants were produced correctly less than 25% of the time by 90% of the children. A longitudinal study conducted by Shriberg, Gruber, and Kwiatkowski (1994) identified patterns of consonant errors in the speech of children over 8 years of age with a history of SSD where early-8 consonants were most commonly substituted, middle-8 consonants were most commonly substituted or omitted, and late-8 consonants were most commonly distorted. One study of a population sample of 7,390 children aged 8–9 years in the United Kingdom identified that 14.3% of the children sampled had some speech sound difficulty (3.6% demonstrated persistent speech disorder) (Wren, Roulstone, & Miller, 2012). Children with ongoing speech difficulties at 8 years of age primarily presented with substitution and distortion errors, but also demonstrated consonant deletion errors and difficulty producing correct lexical stress during connected speech (Wren, McLeod, White, Miller, & Roulstone, 2013).

Although many characteristics of SSD appear to resolve by adulthood, residual articulation errors may be present in the speech of adults with a history of SSD (Felsenfeld et al., 1992; Shriberg, 1993). These residual errors may not impact everyday communication or intelligibility but may be exacerbated in complex speech production contexts. For example, adults with a history of SSD may perform more poorly on polysyllable word production tasks due to the increased phonological load and complexity of polysyllabic words (Lewis & Freebairn, 1992; Lewis et al., 2007). This ongoing difficulty completing complex speech production tasks may suggest an ongoing phonological deficit in adults with a history of SSD.

## Children's speech acquisition

Children acquire speech over many years from the time they are in utero and hearing their mother's voice and native language (Kisilevsky et al., 2009) until they achieve complex speech production in the form of polysyllabic words (James, van Doorn, McLeod, & Esterman, 2008) and rapid and intelligible conversational speech. Early signs of speech development can be observed in the first months of life as children produce cries that mimic the prosody of their family language (Cross, 2009; Mampe, Friederici, Christophe, & Wermke, 2009). These early stages of speech development represent a period of rapid learning as children process, organize, store, and eventually begin to produce early vocalizations and speech sounds.

By the age of 5, children should be able to produce most phonemes within their native language and be intelligible to unfamiliar communication partners (Flipsen, 2006; McLeod, 2009; McLeod, Harrison, & McCormack, 2012a). McLeod and Crowe (2018) conducted a cross-linguistic review of 64 studies of speech acquisition in 27 languages from 31 countries based on 26,007 children and found that, on average, by the age of 5 children produced over 90% of consonants correctly and almost every consonant within their ambient language. However, there are some language-specific differences. For example, in languages such as English where polysyllables occur frequently, children's development of polysyllabic words (words of three or more syllables) with the correct stress, timing, and segmental accuracy is protracted. In fact, the

development of polysyllables in English may continue until 11 years of age for some children (James, 2006; James et al., 2008).

During the first years of rapid learning about speech production, children typically make predictable non-adult productions. Although these non-adult productions are common in many languages, children do not produce the same developmental patterns in every language. Some developmental error patterns are common across different languages. For example, the developmental error pattern of fronting (where a velar sound /k/ is produced as an alveolar sound [t]) has been observed in a number of languages including Cantonese, English, German, Greek, Japanese, Portuguese, Thai, Turkish, Vietnamese, and Welsh (McLeod, 2010). Although the developmental pattern may be common across languages, the expected age for these errors to disappear will be different for each language. Thus, it is important to refer to language-specific information when investigating the errors present in children's speech.

Children's first words are often informed by children's early babble (Stoel-Gammon, 2011). However, there are eight other phonetic, phonological, and lexical factors that may impact children's acquisition of speech, specifically: 1. word frequency, whereby words occurring more frequently in a language are more likely to be produced accurately (Tyler & Edwards, 1993), 2. age of lexical acquisition, in that some words are expected to be acquired at later ages (due in part to word frequency), 3. vocabulary size, in that as children develop a larger vocabulary, their phonological complexity also increases, which may be due in part to more specified phonological representations (Mestala & Walley, 1998) or, vice versa, whereby greater specification of phonological representations forms the basis for greater vocabulary growth, 4. neighborhood density, which indicates the density of words within a lexical neighborhood where words differ only by a single phoneme (Storkel, Maekawa, & Hoover, 2010), with lexical items in dense neighborhoods produced earlier and more accurately than those in sparse neighborhoods (Sosa and Stoel-Gammon, 2012), 5. phonotactic probability, which is the frequency with which a phoneme or combination of phonemes occurs in a given language (Storkel et al., 2010), with some indication that phoneme combinations that occur more frequently may be produced earlier and more accurately (Edwards & Beckman, 2008), 6. phonotactic structure, in that words with more complex phonotactic structures (Brosseau-Lapré & Rvachew, 2014; James et al., 2008; Masso, McLeod, Baker, & McCormack, 2016) or complex consonant clusters (McLeod, van Doorn, & Reed, 2001a, 2001b; Smit et al., 1990) will take longer to acquire accurately than monosyllabic words and words with singleton phonemes, 7. articulatory complexity, in that some phonemes that are easier to produce (i.e., /p, m, w/) than others (i.e., /s, z, ʃ, ʒ/) and easier phonemes will likely be produced earlier (Stokes & Surendran, 2005), and 8. functional phoneme load, where the contrastivity of a phoneme implies the contribution of each phoneme to the recognition of words (Wedel, Kaplan, & Jackson, 2013), with earlier acquired phonemes representing a high functional load (Stokes & Surendran, 2005).

## Assessment of children with suspected SSD

To assess children for the presence of SSD, careful consideration of assessment tools, contexts, and analyses is required to ensure the appropriate differential diagnosis of SSD. Assessing children for the presence or absence of SSD includes determining whether a child can produce all the sounds in the target language, but also should address children's strengths and difficulties, communication partners, environments, needs, expectations, and developmental history. Assessment for SSD is typically completed by a speech-language pathologist. In many cases, children with SSD are referred for an assessment by their parents, educators, or health or medical professionals who notice that the children are difficult to understand. Following this initial identification of

*Table 19.1* Overview of assessment processes to evaluate the presence or absence of speech sound disorders in children.

| *Time of assessment* | *Type of assessment (may include all or some of the following)* |
|---|---|
| Before the assessment | Case history, evaluation of known medical records and reports, discussions with parents and/or education professionals. |
| During the assessment | Single word sampling, connected speech sampling, stimulability testing, intelligibility evaluation, oromuscular assessment, hearing screening, phonemic awareness test, auditory discrimination tasks, classroom observations, perspectives from children, families, and others. |
| After the assessment | Scoring assessments, analyzing the results, and writing the report. |

low intelligibility, a speech-language pathologist is frequently the first person the family talks to about their concerns for their child's communication development. Different assessment tools are used around the world to take into account local language/s, dialect/s, and cultural considerations (McLeod & Verdon, 2014). However, there are fundamental components of the assessment for, and differential diagnosis of, SSD that are common across countries and languages (i.e., Australia: McLeod & Baker, 2014; the Netherlands: Priester et al., 2009; Portugal: Oliveira et al., 2015; the United States: Skahan, Watson, & Lof, 2007; and the United Kingdom: Joffe & Pring, 2008). An overview of different types of assessment tools and purposes can be found in Table 19.1.

The individual components of each assessment are likely to vary from child to child, depending on their needs, parent expectations, and suspected diagnoses. An assessment is likely to include a case history of a child's life to date (i.e., significant medial history, family details, educational details, developmental milestones, and areas of parental concern); assessment of speech production (i.e., single words and connected speech); an evaluation of intelligibility, assessment of oromotor structure and function, speech perception, hearing, phonological processing, literacy ability (if appropriate for age); screening for concomitant communication difficulties (i.e., voice, language, or fluency); and description of the child's social and emotional well-being and participation (McCormack, McLeod, & Crowe, 2019). Assessments should be conducted in an appropriate environment for the child and should be recorded using high-quality audio and/or video recording equipment.

Speech-language pathologists should ensure children's families are actively engaged in the assessment process (Crais, 2009) and may collaborate with other professionals including pediatricians, audiologists, psychologists, early childhood educators, occupational therapists, and/or physiotherapists. An important consideration when undertaking assessments with children, regardless of their clinical presentation, is the need for culturally competent practice, engagement with children's family and community (as appropriate), and the provision of interpreter services if required (Verdon, Wong, & McLeod, 2016). A tutorial paper written by over 40 international experts outlining strategies for assessing children in languages the speech-language pathologist does not speak is available (McLeod, Verdon, & International Expert Panel on Multilingual Children's Speech, 2017).

## Speech analysis

Speech analysis is critical to appropriately characterize children's speech difficulties, hypothesize about the nature of the SSD (i.e., phonological impairment, inconsistent speech disorder,

articulation impairment, childhood apraxia of speech, or dysarthria), determine children's strengths and weaknesses with regard to speech production, identify patterns of errors in children's speech, establish baseline data, and select targets for intervention (if required). Typically, speech-language pathologists will conduct the following analyses:

- Independent analysis: including consonant and vowel inventories of phonemes and any phonetic allophones produced by the child (i.e., lateralized /s/), and a word-structure inventory of CV (consonant-vowel) structures observed.
- Relational analyses: phonological process analysis (i.e., the identification of typical and atypical phonological error patterns as well as the variability of these errors and the patterns of errors across phoneme class, word position, and syllabic context), analysis of lexical stress accuracy, and overall intelligibility.

The Child Speech Disorder Research Network of the United Kingdom and Ireland released a comprehensive report detailing guidelines for the transcription and analysis of children's speech and indicated that undertaking independent and relational analyses is good practice (Child Speech Disorder Research Network, 2017).

Polysyllabic words are diagnostically important in languages such as English (Masso et al., 2016; Murray, McCabe et al., 2015). The analysis of polysyllables may require additional consideration beyond analysis methods utilized for mono- and di-syllabic words. Polysyllables include complex phonotactic shapes and lexical stress patterns that are not considered in most speech analysis methods. There are a few key analysis methods that have been designed specifically for polysyllabic words. Mason, Bérubé, Bernhardt, and Stemberger (2015) developed the nonlinear multisyllabic words metric to address the need for more comprehensive analysis of longer words. This metric aims to determine the accuracy of children's lexical stress, syllables, timing units, and segments. In contrast, Masso (2016) developed the Word-Level Analysis of Polysyllables to identify the frequency of polysyllable errors across seven categories: 1. substitutions of consonants or vowels, 2. deletion of consonants or vowels (including weak syllable deletion), 3. distortion of consonants or vowels, 4. addition of consonants or vowels, 5. alteration of phonotactics, 6. alteration of timing, and 7. assimilation and/or alteration of sequence (full description available in Masso et al., 2016).

There are a number of defined analysis methods used to analyze the speech of children with SSD. For example, the Children's Independent and Relational Phonological Analysis (CHIRPA, Baker, 2016), the Phonological Assessment of Child Speech (PACS, Grunwell, 1985), nonlinear scan analysis (Bernhardt & Stemberger, 2000), systemic phonological analysis of a child's speech (Williams, 2003), and checklists for the identification of features of particular types of SSD (e.g., the American Speech-Language Hearing Association consensus-based feature list for childhood apraxia of speech, ASHA, 2007).

The risk with any one analysis method that focuses specifically on phonology or motor planning is that a speech-language pathologist may miss clinical features within a speech sample due to the analysis guidelines (i.e., it is not always clear that a syllable segregation, a feature of childhood apraxia of speech, would be analyzed within a phonological analysis protocol). Thus, speech-language pathologists need to consider holistic analysis methods.

## Setting goals for children with SSD

Once a child has completed an assessment, and the speech-language pathologist has determined that he or she is eligible and appropriate for intervention services due to the presence of SSD,

the next challenge for the speech-language pathologist is to determine the goals that will be targeted to improve the child's speech.

Although goals are set with a view to improve a child's speech accuracy, and increase intelligibility and participation, the nature of these goals may vary based on the considerations of the type of impairment, the client, and their family. A holistic way to approach goal setting (as well as diagnosis) is to consider children's speech skills, and areas that require improvement, within the context of the International Classification of Functioning, Disability, and Health – Children and Youth version (ICF-CY, WHO, 2007). The ICF-CY framework contextualizes disability and functioning into five different components: 1. Body Structures, 2. Body Functions, 3. Activities and Participation, 4. Environmental Factors, and 5. Personal Factors. Consideration of the ICF-CY framework integrates the child's direct needs to improve speech accuracy with his or her communication needs, environmental factors, and personal considerations.

Ideally, goals for children with SSD should be operationalized: specific, measurable, attainable, realistic, and time-limited (a variation on the S.M.A.R.T. acronym developed by Doran, 1981). Although goals should be well defined, goals for intervention often include session goals (immediate-term goals) (i.e., Justin will produce two-element /s/ consonant clusters correctly in word-initial position on 20 occasions within a single session), short-term goals (i.e., Justin will produce consonant clusters in word-initial and word-final positions to 80% accuracy within a 5 minute conversational speech sample), and long-term goals (i.e., Justin will increase his intelligibility with extended family members based on an average score of 4 or more on the Intelligibility in Context Scale, [McLeod, Harrison, & McCormack, 2012b] within a 12 month period).

Although the structure and planning of intervention goals is important, the crucial factors in setting appropriate goals include determining the correct diagnosis, identifying any concomitant disorders, and evaluating the evidence for the most appropriate approach to intervention and goal setting for that child.

## Intervention for children with SSD: phonological approaches

Children with phonological impairment (including those with inconsistent speech disorder) have cognitive-linguistic difficulties (McLeod & Baker, 2017). Therefore, phonological approaches to intervention need to consider children's development of phonological contrasts, not just an improvement in the ability to produce phones and/or phonemes. There are a number of different approaches to phonological intervention with varying levels of evidence. In a narrative review of the available literature supporting different phonological approaches to intervention written in English, Baker and McLeod (2011) identified 134 published papers that examined phonological intervention. While most of these papers described interventions conducted in English, some examined interventions conducted with multilingual children (e.g., Ray, 2002) or in non-English-speaking countries, including Brazil (Mota, Keske-Soares, Bagetti, Ceron, & Melo Filha, 2007; Pagliarin, Mota, & Keske-Soares, 2009) and Mexico (Pamplona, Ysunza, & Espinosa, 1999) (the language of intervention was not always specified). Of these interventions described in the 134 papers, the majority were individual (not group) interventions (78.7%) completed by a speech-language pathologist (86.9%). The most common session duration was 30 minutes per session (21.3%), and the most common frequency was twice a week (37.2%). Across all of the studies examined, 23 intervention approaches were identified that had more than one published clinical study. Interventions with higher levels of evidence are: minimal pairs therapy (e.g., Ruscello, Cartwright, Haines, & Shuster, 1993; Weiner, 1981), complexity approaches (i.e., maximal oppositions as described by Gierut, 1989; approaches including an empty set, Gierut, 1992), and cycles (e.g., Mota et al., 2007). Morphosyntax intervention (e.g.,

Tyler, Lewis, Haskill, & Tolbert, 2003), core vocabulary (e.g., Crosbie, Holm, & Dodd, 2005), and traditional articulation therapy (e.g., Pamplona et al., 1999) also have reasonable evidentiary support. Two fundamental differences between intervention approaches are: 1. the selection of intervention targets, and 2. the method/s by which phonological contrasts and phonological knowledge are taught within each clinical encounter. While a body of evidence exists for using interventions with English-speaking children, it is important to consider the relevance of interventions to other languages. For example, minimal pairs intervention may be relevant for languages such as English, Spanish, Cantonese, and Vietnamese, but not for multimorphemic languages such as Icelandic. For more information (and videos) about undertaking specific interventions see Williams, McLeod, and McCauley (2010).

The selection of intervention targets for children with phonological impairment may be undertaken according to a traditional, developmental approach to intervention (e.g., Rvachew & Nowak, 2001) or according to a complexity approach to intervention (e.g., Gierut, 2007). The developmental approach to target selection assumes that the best targets are those that occur frequently, include early developing phonemes (i.e., /p, b, t, d/), impact intelligibility, and are already present (stimulable) in a child's sound system (Dyson & Robinson, 1987). In contrast, a complexity approach to intervention assumes that the best targets are those that are not present in a child's sound system (non-stimulable) and are phonetically complex (i.e., later-developing sounds and consonant clusters) (Gierut, 2007). Although seemingly counter-intuitive, a complexity approach to target selection has resulted in generalization across non-target phonemes (e.g., Gierut, 1999; Gierut & Champion, 2001; Powell, Elbert, & Dinnsen, 1991). Core vocabulary intervention has been designed to support children with inconsistent speech disorder (Dodd, Holm, Crosbie, & McIntosh, 2006, 2010). The approach focuses on consistency of production of words that are important for the child (McIntosh & Dodd, 2008).

In addition to considering the approach to intervention and intervention targets, the optimum intensity for the intervention is important (Warren, Fey, & Yoder, 2007). Intensity includes the frequency of teaching moments within an intervention session, the type of task that is designed to encourage the target behavior, the number of times the child is exposed to the *active* learning opportunity in a session, the frequency of intervention sessions, the total duration of intervention, and the sum of all intervention combined (Warren et al., 2007). An example of how to consider and document intervention intensity was presented by Baker (2012). In her summary of known factors that contribute to intervention intensity, Baker highlighted the considerable challenges in determining the optimum intensity to see change during intervention for children with phonological impairment. A low intervention intensity will likely have minimal effect on children's development of appropriate speech (Law & Conti-Ramsden, 2000).

## Intervention for children with SSD: articulatory and motor speech approaches

Articulatory and motor approaches to intervention differ from phonological approaches to intervention in a number of fundamental ways. Firstly, the fundamental principles of motor learning inform much of the approach to intervention (Maas et al., 2008). To learn a new motor skill (whether it be riding a bike or learning to say the phoneme /s/) there are two distinct phases of acquisition of the new skill: pre-practice and practice. The pre-practice phase includes establishing that the child has the motivation for the learning task, ensuring an understanding of the task requirements, and providing the opportunity to attempt to produce the target response. The practice phase is the opportunity for children to complete repetitive trials of the target motor speech movement with varying degrees of feedback from their speech-language

pathologist. Within the practice phase, different conditions of practice can be manipulated to ensure each child gets the optimum number of practice opportunities, at the right time, within the right context, and with maximally appropriate feedback. The type of feedback during each of these phases can also encourage motor learning. The two types of feedback provided are knowledge of performance (i.e., providing specific information to the children regarding what they did correctly/incorrectly) and knowledge of results (i.e., indicating to the children whether their productions were correct or incorrect). Both types of feedback can be provided during the pre-practice phase, but it has been recommended that only knowledge of results feedback should be provided during the practice phase (Maas et al., 2008).

The structure, timing, and variability of practice may contribute to children's learning of new motor skills. It has been suggested that large amounts of practice that are distributed over a long period of time, including variable (i.e., different contexts for each phoneme target), random (i.e., the order of target practice changes from trial to trial), and complex (i.e., later-acquired phonemes and phonotactic sequences) targets will encourage children to achieve deep, long-term learning of motor speech targets. Further, it was suggested that encouraging children to maintain external attentional focus (i.e., on the way a phoneme sounds) may also support motor speech learning (Maas et al., 2008; Maas, Butalla, & Farinella, 2012; Maas & Farinella, 2012).

Considering that the approach to motor speech learning may stay relatively consistent, it is the selection of intervention targets that plays the key role in intervention for different types of motor speech difficulties. The goals and intervention for an articulation disorder characterized by an isolated distorted consonant (i.e., a lateral /s/) will be different from the goals and intervention for childhood apraxia of speech and childhood dysarthria.

The approach to intervention for children with articulation impairment in isolation frequently follows a traditional articulation therapy approach (van Riper, 1939). For this intervention, target phonemes are selected based on children's speech errors and are practiced in a hierarchical manner from least complex contexts (i.e., in isolation) to most complex contexts (i.e., in conversational speech). Articulation therapy may be enhanced through the provision of biofeedback to support children to learn where and how to move their articulators using techniques such as ultrasound and electropalatography (Cleland, Scobbie, & Wrench, 2015; Preston et al., 2014).

There are three main approaches to supporting children with childhood apraxia of speech: 1. Nuffield Centre Dyspraxia Program (NDP3, Williams & Stephens, 2004), 2. Dynamic Temporal and Tactile Cueing for Speech Motor Learning (DTTC, Strand, Stoeckel, & Baas, 2006), and 3. the Rapid Syllable Transition Treatment (ReST, Ballard, Robin, McCabe, & McDonald, 2010; McCabe, Thomas, & Murray, 2016). NDP3 builds children's speech production accuracy up through layers of intervention, initially focusing on consonant (C) and vowel (V) phonemes in isolation and then moving to gradually more complex combinations of target sounds (e.g., CVC, CCVC). DTTC is a structured intervention designed for children who find phoneme imitation challenging and require maximal support to produce oral targets. In addition, DTTC focuses intervention on the transitions between phonemes through modifying and simplifying speech contexts during practice. DTTC milestones include the gradual reduction in support provided by the speech-language pathologist from highly supported contexts (i.e., the production of targets and prolonged vowels concurrent between the child and the clinician) to unsupported contexts (i.e., spontaneous production). It is suggested that DTTC is most suitable for children with severe childhood apraxia of speech (including those who are non-verbal). ReST differs in that it is the only motor speech intervention that relies on practising nonword targets (words that adhere to the phonological and phonotactic rules of the target language but are not meaningful) and commences intervention with the production of two- or three-syllable words.

ReST is most suitable for children who have mild-moderate childhood apraxia of speech and has been found to be as effective in the immediate term as NDP3 but with greater longitudinal outcomes (Murray, McCabe, & Ballard, 2015).

Due to the heterogeneous presentation of dysarthria in children, and the likely involvement of physiological systems beyond motor speech planning of oral articulators (e.g., the respiratory system) (Love, 2000), planning for intervention requires careful consideration. Children who present with articulatory errors with limited involvement of other systems may be suitable for traditional articulation therapy (Hustad, 2010). Other interventions for children with dysarthria include Prompts for Restructuring Oral Muscular Phonetic Targets (PROMPT) (Ward, Leitão, & Strauss, 2014), a systems approach (Pennington, Miller, Robson, & Steen, 2010), and Lee Silverman Voice Treatment (LSVT LOUD, Fox & Boliek, 2012). An alternate approach to intervention for children with significant SSD is the augmentation of oral communication using augmented and alternative communication systems (e.g., a picture communication system).

## Impact of SSD

SSD can impact communication, academic, social-emotional, and occupational outcomes across the lifespan (McCormack, McLeod, McAllister, & Harrison, 2009). To examine the effect of SSD across the lifespan, a number of longitudinal studies demonstrated the longer-term consequences of SSD: 1. the Templin Longitudinal Study (Felsenfeld et al., 1995), 2. the Ottawa Language Study (Johnson, Beitchman, & Brownlie, 2010), and 3. the Cleveland Family Speech and Language Study (Lewis et al., 2015). Residual effects of early SSD were present in the speech of adults in each of these longitudinal studies (Beitchman et al., 2001; Felsenfeld et al., 1992; Johnson et al., 2010). Although a history of SSD may appear to "resolve" in childhood, the residual effects of SSD may still be present, particularly during the completion of complex speech tasks (i.e., polysyllabic words) (Lewis et al., 2015). A history of SSD also appeared to influence educational outcomes of the participants in each study (Felsenfeld, Broen, & McGue, 1994; Johnson et al., 2010) and, specifically, development of literacy skills in adolescence (Lewis et al., 2015). Although there was evidence of residual speech errors in some participants, there was no significant difference between adults with and without a history of SSD on measures of socio-emotional adjustment (Felsenfeld et al., 1994) or ratings of quality of life (Johnson et al., 2010).

### *Attitudes*

In childhood, SSD can impact children's attitudes towards talking and how they perceive the communicative skill of their communication partners. In one study of 13 preschool children, children with SSD appeared to attribute communication breakdown to their communication partner's lack of listening skills, not their own ability to produce intelligible speech (McCormack, McLeod, Harrison, & McAllister, 2010). Although the perception of the *cause* for communication breakdown differs, the impact of impaired communication can be considerable for the social experiences of children with SSD (Markham & Dean, 2006; Markham, van Laar, Gibbard, & Dean, 2009; McCormack et al., 2010; McLeod, Daniel, & Barr, 2013), their siblings (Barr, McLeod, & Daniel, 2008), families (Cambra, 1996; Macharey & von Suchodoletz, 2008), and their interactions at school (Daniel & McLeod, 2017). These effects can even extend into adolescence and adulthood. Peers of adolescents with mild SSD may demonstrate negative attitudes towards the individual with SSD (Silverman & Falk, 1992; Sweeting & West, 2001), and adults with persistent SSD have reported ongoing negative social experiences due to the effects

of their speech on social engagement and their occupation (Veríssimo, van Borsel, & de Britto Pereira, 2012).

### *Impact on education*

Children with SSD may require education support (Felsenfeld et al., 1994), are more likely to prematurely discontinue their education (Robertson, Harding, & Morrison, 1998), and are less likely to attend higher education (beyond high school) than children without SSD (Felsenfeld et al., 1994). One of the primary considerations when exploring the educational impact of SSD is children's development of literacy. Children with SSD have long been identified to be at risk of literacy difficulties (Anthony et al., 2011; Bird, Bishop, & Freeman, 1995; Bishop & Adams, 1990; Foy & Mann, 2012; Larrivee & Catts, 1999; Nathan et al., 2004; Raitano, Pennington, Tunick, Boada, & Shriberg, 2004). Debate remains over the impact of isolated SSD on the attainment of educational milestones. Some authors have concluded that isolated SSD may not impact literacy acquisition but that concomitant SSD and developmental language disorder had a considerable impact on children's literacy acquisition (e.g., Bishop & Clarkson, 2003). A history of SSD and developmental language disorder may also impact children's mathematical skills (Harrison, McLeod, Berthelsen, & Walker, 2009; McCormack, Harrison, McLeod, & McAllister, 2011). In addition to finding literacy and numeracy challenging, children with SSD are also reported by teachers to experience greater social, emotional, and educational difficulties (Daniel & McLeod, 2017; Overby, Carrell, & Bernthal, 2007). Challenging educational experiences may also impact the occupational attainment and experiences of individuals with SSD. Individuals with SSD are more likely to enter unskilled or semiskilled workplaces than individuals with no history of SSD (Felsenfeld et al., 1994) and may be subjected to workplace discrimination (Mitchell, McMahon, & McKee, 2005) or negative attitudes at work (Chan, McPherson, & Whitehill, 2006; Scheuerle, Guilford, & Garcia, 1982).

## Summary

Children with SSD are a heterogeneous group who constitute a large portion of the caseload of speech-language pathologists around the world. Although there are many known causes for SSD, the origin of SSD cannot be identified for many children. Speech-language pathologists should consider children with SSD holistically during assessment to provide them with intervention that is best informed by available evidence. The implementation of appropriate early intervention and multidisciplinary support for children with SSD and their families is important to reduce the impact that SSD may have on children's social, emotional, academic, and occupational experiences across the lifespan.

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# 20

# LANGUAGE ABILITIES AND LANGUAGE GROWTH IN CHILDREN WITH HEARING LOSS

*Teresa Y. C. Ching, Linda Cupples, and Vicky W. Zhang*

## Introduction

Although typically developing children generally produce their first words at around 12 months of age, a great deal of learning and development goes on in the year prior to that impressive achievement. Gervain and Mehler (2010) surveyed the literature and concluded that during the first year of life, infants' speech perception ability contributes not only to the development of acoustic, phonetic, and phonological aspects of language but also to later morphosyntax. They cited evidence that infants can use word-level stress patterns, phonotactic regularities, and allophonic variation to identify word boundaries in the speech stream, which is widely acknowledged as a crucial early step in the process of acquiring a spoken vocabulary (e.g., Shi, Cutler, Werker, & Cruickshank, 2006; Swingley, 2009). In the words of Pinker (1994, p. 161), "speech perception is . . . one of the biological miracles making up the language instinct."

In light of the important role played by speech perception in early spoken language development, it is not surprising that young children with permanent childhood hearing loss (PCHL) generally perform below the level of their hearing peers on assessments of spoken language (e.g., Boons et al., 2013; Ching, Dillon, et al., 2013; Cupples, Ching, Button, Seeto, et al., 2018). An important question, however, is the extent to which early delays in spoken language can be overcome in children who receive audiological intervention, in the form of hearing aids (HAs) or cochlear implants (CIs). The basic function of a HA is to amplify sounds across a wide frequency range to levels well above the listener's hearing thresholds. The aim is to maximize the amount of the speech spectrum that is audible to the user of HAs. When hearing loss is severe to profound, direct electrical stimulation of the auditory nerve with CIs rather than acoustic amplification with HAs is necessary to improve audibility of sounds. An intended effect of fitting HAs or CIs is to enhance speech and language development through increasing access to sounds, and it may be expected that earlier access is likely to reduce the deleterious effects of PCHL on child language development.

Universal newborn hearing screening (UNHS) has been widely implemented since 2000 to detect congenital hearing loss soon after birth, so that treatment can begin in infancy before language delays set in. De Villiers, De Villiers, and Hoban (1994) suggested that three factors are crucial to acquisition of a first language: 1. an innate language acquisition mechanism; 2. the natural unfolding of biological and cognitive factors with maturation; and 3. experience with

high-quality inputs. The presence of a hearing loss may be expected to have a negative impact on the third factor, but should not affect the first two factors unless the hearing loss is accompanied by other disabilities. Accordingly, we would examine language acquisition of children with PCHL separately from those who also have additional disabilities. This chapter provides an overview of current evidence on the effect of early amplification or cochlear implantation and other factors on language development of children who have PCHL with or without comorbidities; examines the language growth observed in the preschool years; and discusses the implications for language intervention for children with hearing loss.

## Language acquisition in children with PCHL

Language delay affects more than 40% of children with PCHL by 4–5 years of age (Cupples, Ching, Button, Leigh, et al., 2018; Geers, Moog, Biedenstein, Brenner, & Hayes, 2009), compared to 5%–10% of children with typical hearing (Law, Boyle, Harris, Harkness, & Nye, 2000; Norbury et al., 2016). Children with language problems have higher rates of behavioral and emotional problems (Benner, Nelson, & Epstein, 2002; Wong et al., 2018), educational difficulties, and academic underachievement (Snowling, Adams, Bishop, & Stothard, 2001). Emerging evidence is showing that language deficits in children with PCHL could be alleviated, and in some instances prevented, through early treatment (Fulcher, Purcell, Baker, & Munro, 2012). It has also been recognized that early treatment is essential but not sufficient, that a range of factors influence outcomes, and that when the influence of hearing loss is taken into account, the factors vary in effect size according to whether children use HAs or CIs (Ching, Dillon, Leigh, & Cupples, 2018).

### *Children using HAs*

There is no doubt that amplification can reduce the impact of hearing loss on children's lives. The fitting of HAs increased audibility of sounds and auditory access to language inputs (Ching, Johnson, et al., 2013; Ching, Quar, Johnson, Newall, & Sharma, 2015), which would be expected to support language development. A recent study by Tomblin, Oleson, Ambrose, Walker, and Moeller (2014) measured the extent to which amplification improved speech production and language outcomes in 180 children with mild to severe hearing loss who were assessed at 3 or 5 years of age. There was a small-to-moderate but significant correlation between aided hearing and outcomes, suggesting a clear benefit of amplification. The amount of audibility provided by amplification depends on the quality of HA fitting – whether a validated prescription procedure was used to derive individualized targets, whether HAs were verified to match targets by using real-ear measurements, and whether the effectiveness of the HAs was evaluated to optimize effectiveness (American Academy of Audiology Task Force on Pediatric Amplification, 2013; Ching, Johnson, et al., 2013; King, 2010). The influence of HA fitting according to clinical best practice has been clearly affirmed, but receiving higher HA gain than what was prescribed by validated HA prescription procedures did not account for unique variance in language abilities (Ching, Zhang, Johnson, et al., 2018; Tomblin et al., 2015). Furthermore, as HAs cannot increase audibility unless they are worn, consistent usage of HAs was related to early language development (Tomblin et al., 2015). However, more hours of usage was not associated with higher scores on functional performance in real life as measured by a parent-report tool (the Parents' Evaluation of Aural/Oral Performance of Children rating scale, Ching & Hill, 2007) or word recognition scores at 3 years or older (McCreery et al., 2015).

## Age at amplification

There is now solid evidence on the benefit of early fitting of HAs for child language outcomes at 5 years of age. Language delay in children with PCHL is abatable, or in some cases completely preventable. A population-based prospective study, the Longitudinal Outcomes of Children with Hearing Impairment (LOCHI) study, showed a clear benefit of early HA fitting, and the effect size was greater for children with more severe hearing loss (Ching et al., 2017). Compared with HA fitting at 24 months of age, language scores at 5 years of age measured using directly administered standardized tests were 0.8 SD (−11.8 score points, 95% confidence interval: −18.7 to −4.8) and 0.55 SD (−6.8 score points, 95% confidence interval: −10.8 to −2.8) higher in children with 70 dB HL and 50 dB HL respectively with amplification at 3 months of age. The earlier a child receives HAs, the better are the language and speech perception outcomes at 5 years of age. These effect sizes were observed after adjustments for nonverbal IQ, birth weight, additional disabilities, maternal education, sex, socio-economic status, and communication mode in a large cohort of 350 children fitted with HAs before 3 years of age. The study controlled for post-diagnostic audiological intervention, as all children received uniform hearing services and high-level technology from a single government funded national service provider, at no cost to families. Unlike previous population-based studies that included very few children who received HAs at a young age (e.g., only 11 children were fitted with HAs before 6 months in Wake, Hughes, Poulakis, Collins, & Rickards, 2004, and the median age at fitting for children who were screened at birth was around 15 months in Korver et al., 2010), the median age at HA fitting for the children whose hearing loss was diagnosed through newborn hearing screening in the LOCHI study was 3.9 months (interquartile range: 2.3 to 10.1). The cohort is representative of the general population of children with PCHL in Australia.

The findings from the LOCHI study extend previous knowledge on the positive effect of age at diagnosis in other population-based studies (Kennedy et al., 2006) by quantifying the positive effect of age at intervention for children with different degrees of hearing loss. Methodological aspects including small sample size (e.g., Fitzpatrick, Crawford, Ni, & Durieux-Smith, 2011; Stiles, Bentler, & McGregor, 2012), confounding effects of various demographic characteristics, delays in HA fitting after diagnosis or delays in diagnosis after screening, and different ages and methods of testing likely explain the divergent findings reported in previous studies. Fitzpatrick et al. (2011) compared language abilities between 26 screened and 39 unscreened children enrolled in a certain early education program, and did not find a significant difference in receptive and expressive language outcomes between the two groups. Stiles et al. (2012) found that characteristics of HA fitting, but not age at first fitting of HAs, affected receptive vocabulary measured at 6 to 9 years of age in 16 users of HAs. Koehlinger, Owen van Horne, and Moeller (2013) reported that the age of the children, aided audibility, and degree of hearing loss predicted mean length of utterances and use of verb morphology in children at 3 and 6 years of age. Tomblin et al. (2015) examined the effect of age at HA fitting on children's language measured in the preschool years, and reported a trend for the impact of age at HA fitting to decrease with age at testing, such that by 6 years of age, they predicted no significant difference in language scores between those who were fitted with HAs between 7 and 12 months of age compared to those fitted between 13 and 60 months. However, the authors suggested that the effect of age at HA fitting was confounded with the effect of duration of HA experience. The effect of age at HA fitting observed in children tested at a younger age was likely due to the longer duration of HA use at the time of testing. For two children evaluated at 3 years of age, the child fitted with HAs at age 6 months would have 2.5 years of HA experience whereas the one fitted

at age 2 years 6 months would have used HAs for only 6 months. This effect of age at HA fitting (or duration of HA use) became nonsignificant when the children were tested by 6 years of age.

### *Other factors*

In addition to age at HA fitting, Cupples, Ching, Button, Seeto, et al. (2018) found that language outcomes in the LOCHI cohort were influenced by nonverbal cognitive ability, severity of hearing loss, maternal education, and communication mode. More specifically, an increase of 15 standard score points on the Wechsler Nonverbal scale of ability (WNV) was associated with an improvement of about 12.8 standard score points in receptive language and 10.2 standard score points in expressive language, both measured using the Preschool Language Scale, fourth edition (PLS-4) (Zimmerman, Steiner, & Pond, 2002). Similar improvements in language outcomes were associated with an increase in maternal level of education from school to diploma (with increases of 10.7 and 9.3 standard score points for receptive and expressive language respectively) and from school to university (with corresponding increases of 10.0 and 9.1). Use of oral communication only in early intervention was linked to an improvement in language scores of 9.5 (receptive) and 7.6 (expressive). With regard to the impact of increased severity of hearing loss, for children who were first fitted with HAs at 12 months of age, receptive and expressive language scores dropped by 3.5 and 2.9 standard score points respectively for every 10 dB increase in hearing loss in the better ear.

These findings are broadly consistent with those reported in previous literature. Wake, Poulakis, Hughes, Carey-Sargeant, and Rickards (2005) found that severity of hearing loss was a significant factor influencing the language of children with hearing loss measured at 7–8 years of age in a population-based study. The association of poorer language outcomes with greater severity of hearing loss has also been reported in other studies of English-speaking children (Fitzpatrick et al., 2011; Koehlinger et al., 2013) and French-speaking adolescents (Delage & Tuller, 2007). The significant influence of maternal education is also consistent with that reported by Fitzpatrick et al. (2011) using similar outcome measures.

## *Children using CIs*

### *Age at implantation*

The LOCHI study has provided population-based evidence on the benefit of early age at cochlear implantation for improving language outcomes at 5 years of age. Compared to implantation at 24 months, language scores at 5 years of age were 1.4 SD higher with implantation at 6 months of age (Ching et al., 2017). All 104 children in the study received a CI before 3 years of age, 39 before 12 months of age. The study found that the earlier the implantation, the greater the benefit, at least over the age at implantation range of 6 to 35 months. This significant effect of age at implantation has been observed at 3 years of age (Ching, Dillon, et al., 2013), and the effect size is even larger at 5 years of age (Cupples, Ching, Button, Seeto, et al., 2018). These findings are consistent with findings for specific age groups reported in the literature. Leigh, Dettman, Dowell, and Briggs (2013) demonstrated better vocabulary scores for preschoolers who received their first CIs before 12 months of age compared to those who received an implant between 12 and 24 months. Geers and Nicholas (2013) showed that age at implantation explained 15% of variance in the language scores of 60 children who received their first CIs before 3 years of age.

In a longitudinal study, Nittrouer and Chapman (2009) showed that age at implantation was a significant predictor of language outcomes of children with bilateral CIs only for the 24 who ceased wearing a HA after they received their first CI but not for the 26 who continued to wear a HA with their CI in opposite ears (bimodal fitting) until they received a second CI. It was found that those with bimodal experience had better language than those without bimodal experience, after allowing for the effect of socio-economic status. The authors posited that the use of a HA with a CI may have supported the perceptual organization of the degraded signal received through a CI. However, the LOCHI study findings are not consistent with this supposition. Age at implantation was a consistent predictor of speech perception ability for all children using CIs, regardless of whether they were using unilateral CIs (n = 12), a CI and a HA in opposite ears (bimodal fitting, n = 16), or bilateral CIs (n = 56). On average, there were no significant between-group differences in speech perception ability after allowing for the effects of nonverbal cognitive ability (Ching, Zhang, Flynn, et al., 2018).

Most past research examining effects of age at implantation on language outcomes was conducted with English-speaking participants. By contrast, Boons et al. (2012) evaluated both receptive and expressive language outcomes in 288 Dutch-speaking children in Belgium and the Netherlands. All participants in the study received their CIs before 5 years of age; and completed standardized language assessments on a yearly basis for 3 years after implantation. The results showed that age at implantation had a significant influence on outcomes, with an implant age of 2 years or below deemed necessary to avoid long-term negative effects on outcomes.

### *Other factors*

In addition to age at CI fitting, Cupples, Ching, Button, Seeto, et al. (2018) reported that nonverbal cognitive ability and the presence of additional disabilities were significant factors influencing receptive language, expressive language, and speech production. More specifically, an increase of 15 standard score points on the WNV was associated with an improvement of about 12.0 standard score points in PLS-4 receptive language and 9.0 standard score points in PLS-4 expressive language. The presence of one or more additional disabilities had a negative impact on language outcomes, being associated with a reduction of 22.4 standard score points in PLS-4 receptive language and 19.5 standard score points in PLS-4 expressive language.

While these findings are consistent with previous research examining the outcomes associated with cochlear implantation (Geers et al., 2009; Geers, Nicholas, & Sedey, 2003), they differ from the findings described above for children with HAs. Whereas maternal education was a significant predictor of outcomes in HA users, it was not associated with the outcomes achieved by CI users. This difference in findings cannot be attributed to a relative lack of variability in levels of maternal education within the group of CI users, because the distribution of participants across educational levels was similar for the two groups. Cupples, Ching, Button, Seeto, et al. (2018) concluded that interpretation of this apparent group difference requires further, more targeted investigation.

## *Children with PCHL and additional disabilities using HAs or CIs*

About 20%–40% of children born with PCHL have a significant additional disability (Gallaudet Research Institute, 2011). These children achieve poorer language outcomes than those with no additional disabilities, as shown in studies of English-speaking (Ching, Dillon, et al., 2013) and Dutch-speaking (e.g., Boons et al., 2012) participants.

## *Benefit of amplification or cochlear implantation*

There is a scarcity of research on the benefits of HAs in this population. Kaga et al. (2007) examined auditory outcomes in 28 children with comorbidities who were fitted with HAs between 1 and 5 years of age. Seventeen of the children showed improved auditory behaviors, five did not show benefits, and six did not use HAs after fitting. Details about severity of hearing loss and other demographic characteristics were lacking, making it difficult to interpret the findings.

Most other published studies have focused on the benefit of cochlear implantation, showing that children with PCHL and additional disabilities received benefits, albeit at a slower pace and/or to a lesser extent, compared to children without additional disabilities. The outcomes were highly variable. Waltzman, Scalchunes, and Cohen (2000) reported on 29 children who received their CIs between 1.9 and 12 years of age, indicating a gradual increase in auditory-linguistic abilities from pre-implantation to 8 years post-implantation. At the final post-implantation assessment, scores ranged from below 10% to greater than 90% on all of the open-set speech recognition tasks. Hamzavi et al. (2000) reported on 10 children with additional disabilities who received their CIs between 8 and 88 months of age, and whose assessments at 12 to 55 months after implantation revealed marked variations. Two children could recognize spoken words and sentences, three could produce or understand a few spoken words, and the remaining five did not develop any speech perception or production skills. High variability in outcomes after implantation was also reported by Donaldson, Heavner, and Zwolan (2004) for seven children with autism spectrum disorder who received their CIs between 3 and 9 years of age. Four of the seven children were not able to complete formal assessments of expressive and receptive vocabulary, or open-set speech recognition of familiar words or phrases. However, parent ratings of communicative skills showed consistent improvement after implantation in the children's abilities to react to sounds, make eye contact, respond to verbal requests, and attend to people.

## *Age at intervention (hearing device fitting)*

The LOCHI study found that age at intervention was a significant predictor of language outcomes measured at 5 years of age in this large cohort of 146 children with additional disabilities, after allowing for the effects of a range of demographic characteristics (Cupples, Ching, Button, Leigh, et al., 2018). This study provides solid evidence that attests to the importance of providing early intervention to children with PCHL who also have additional disabilities. Earlier evaluations of the cohort at 3 years of age showed a different pattern of results in that language outcomes were not associated with age at either CI or HA fitting. The earlier age at testing might not have provided sufficient scope for the effect of early intervention to be observed (Fitzpatrick, Durieux-Smith, Eriks-Brophy, Olds, & Gaines, 2007). Assessments conducted at 5 years of age also showed increased reliability and validity of test results achieved by children compared to measures at a younger age as they became more able to cope with the demands of direct assessments.

Differences in methodology, age at testing, and sample size and characteristics might explain the variation in findings reported in previous studies. Meinzen-Derr, Wiley, Grether, and Choo (2010) found that after controlling for nonverbal cognitive ability, earlier age at diagnosis of hearing loss was not associated with better receptive and expressive language outcomes measured using directly administered standardized tests. In a subsequent study, Meinzen-Derr, Wiley, Grether, and Choo (2011) reported that neither age at CI switch-on nor degree of hearing loss accounted for significant unique variance in children's language scores, after controlling for nonverbal cognitive ability. Using a parent report scale, Beer, Harris, Kronenberger, Holt, and Pisoni (2012) also found a nonsignificant association between age at CI switch-on and outcomes.

### *Other factors*

In addition to effects of age at intervention, the LOCHI study found that better language outcomes at 5 years of age were associated with lesser degrees of hearing loss, higher levels of cognitive ability, use of speech for communication in early intervention, and higher levels of maternal education (Cupples, Ching, Button, Leigh, et al., 2018). These findings are consistent across a range of outcome measures, including receptive and expressive language and speech production assessed using standardized tests directly administered to participants and parent reports for a large cohort of children evaluated at 5 years of age. These same factors were found to influence outcomes measured at 3 years of age (Cupples et al., 2014), with the exception of nonverbal cognitive ability, which was not measured at 3 years of age but was likely reflected in the variable of "disability type".

Earlier evaluations of the cohort at 3 years of age showed that the type of additional disability was the strongest predictor of children's receptive and expressive language outcomes (Cupples et al., 2014). On average, children with autism, cerebral palsy, and/or developmental delay achieved consistently poorer language scores than those with other disabilities not entailing developmental delay. This group difference undoubtedly reflected, in part, variation in cognitive ability, as there were marked differences in nonverbal IQ standard scores between disability groups when measured at 5 years of age. Better language ability was also linked to higher levels of maternal education at 3 years, especially for the former group (i.e., children with autism, cerebral palsy, and/or developmental delay).

## Language growth during preschool years

Investigations of the way in which language develops over time, or trajectories, are of theoretical interest, because they provide an empirical basis for claims regarding the extent to which later-developing language skills build on various child- and family-related factors and the integrity of earlier acquired skills and abilities. They are also of clinical interest because of their potential value in helping to discriminate, for example, between children who have language difficulties that are likely to resolve spontaneously, and those whose difficulties are likely to persist in the absence of appropriate intervention. Importantly, they might also enable us to identify children whose language appears to be developing normally at first, but who go on to experience later language difficulties.

### *Children with normal hearing*

Recent studies on children who have typical development have revealed considerable instability in language growth, especially during the preschool years (see Chapter 17, this volume). Two Australian studies summarized in Table 20.1 illustrate this lack of stability.

Ukoumunne et al. (2012) reported on language development from 8 months to 4 years of age in a large sample of 1,113 children born in Melbourne, Australia. Although the children were successfully assigned to trajectory subgroups with stable, improving, or declining language abilities, the researchers acknowledged the heterogeneity within identified subgroups, which according to them "precludes practical use of this knowledge for early accurate screening and identification of children with language impairments" (p. 346). McKean et al. (2017) reported a subsequent study of 1,279 children drawn from the same cohort, ages 4 to 11 years. They also provided evidence of trajectory subgroups, which were stable (94% of children), low-decreasing (4%), and low-improving (2%). Unlike Ukoumunne et al., however, McKean et al. concluded

*Table 20.1* Summary of a representative sample of papers examining language trajectories in children with typical and atypical development.

| *Author(s), year* | *Participants (N, age)* | *Trajectories (n)* | *Characteristic and differentiating features* |
|---|---|---|---|
| Ukoumunne et al. (2012) | *N* = 1,113<br>*Ages* = 8, 12, 24, 36, and 48 months<br>*Measures* = Parent report CSBS (at 8, 12 months); Parent report MacArthur-Bates CDI (at 24, 36 months); CELF Preschool 2 (at 48 months) | 1. Typical (837)<br>2. Precocious – late (112)<br>3. Impaired – early (69)<br>4. Impaired – late (53)<br>5. Precocious – early (42) | • At 4 years of age, three distinct groups remain: *Typical* (i.e., Typical, Impaired early, and Precocious early); *Precocious* (i.e., Precocious late); and *Impaired* (i.e., Impaired late)<br>• Improving language profiles (Precocious late, Impaired early) are linked to increased levels of maternal education and vocabulary, and high socio-economic status |
| McKean et al. (2017) | *N* = 1,279<br>*Ages* = 4, 5, 7, and 11 years<br>*Measures* = CELF Preschool 2 (at 4 years); CELF 4 (at 5, 7, and 11 years of age) | 1. Stable (1,199)<br>2. Low-decreasing (50)<br>3. Low-increasing (30) | • *Low-decreasing vs. Stable:* Low-decreasing more likely to have lower nonverbal cognition; low birth weight; a diagnosis of learning disability; lower family literacy; 10–20 children's books at home; parents who sought additional support<br>• *Low-increasing vs. Stable:* Low-increasing more likely to have non-English-speaking background; lower nonverbal cognition and socio-economic status; <10 children's books at home; and not have low birth weight<br>• *Low-decreasing vs. Low-increasing:* Low-decreasing more likely to have low birth weight and <10 children's books at home; and less likely to have non-English-speaking background |

| *Author(s), year* | *Participants (N, age)* | *Trajectories (n)* | *Characteristic and differentiating features* |
|---|---|---|---|
| Armstrong et al. (2017) | *N* = 783<br>*Ages* = 2 and 10 years<br>*Measures* = Language Development Survey (at 2); CELF-3 (at 10) | 1. Consistently typical (511)<br>2. Deteriorating (182)<br>3. Improved (46)<br>4. Consistently low (44) | • *Consistently typical vs. Deteriorating:* Increased risk of deteriorating language trajectory associated with maternal smoking during pregnancy, paternal incomplete secondary education, low family income, limited exposure to reading at 2 years, and being male<br>• *Consistently low vs. Improved:* Increased risk of consistently low trajectory associated with maternal smoking during pregnancy |
| Snowling et al. (2016) | *N* = 220<br>*Ages* = 3.5, 5.5, and 8 years<br>*Measures* = CELF-Preschool 2 and TEGI at 3.5; CELF4, TEGI, and TROG II at 5.5 and 8 | 1. Typical (145)<br>2. Resolving (12)<br>3. Emerging (21)<br>4. Persisting (42)<br>NB: Language impairment defined as falling −1 SD below the mean | • *Typical vs. Resolving:* Resolving have lower nonverbal cognition at 3.5<br>• *Typical vs. Persisting:* Persisting have lower nonverbal cognition at 3.5, and a higher percentage of boys<br>• *Typical vs. Emerging:* Emerging have lower nonverbal cognition at 3.5 and more children at family risk of dyslexia<br>• *Persisting vs. Resolving:* Resolving have higher nonverbal cognition, better comprehension, and better vocabulary at 3.5, but poorer grammar |

*Note:* CSBS = Communication and Symbolic Behavior Scales (CSBS) – Infant Toddler Checklist; MacArthur-Bates CDI = MacArthur-Bates Communicative Development Inventories; CELF Preschool 2 = Clinical Evaluation of Language Fundamentals Preschool, second edition; CELF4 = Clinical Evaluation of Language Fundamentals, fourth edition; TEGI = Test of Early Grammatical Impairment; TROG II = Test for Reception of Grammar, second edition; CELF3 = Clinical Evaluation of Language Fundamentals, third edition.

that "by 4 years, services can be confident that children with low language will remain low over the primary years" (p. 9). The findings from these two studies are consistent with Norbury's claim (Chapter 17, this volume) that the stability of scores within a given cohort will depend partly on the timing of assessments.

Other Australian research has supported the growing body of evidence illustrating the highly variable nature of children's early language trajectories (e.g., Armstrong et al., 2017). As noted by Norbury (Chapter 17, this volume), however, language skills are much more stable after school entry than before, which may not bode well for children who begin school with low levels of language proficiency. In accordance with this view, Snowling et al. (2016) demonstrated the association between early language trajectory and later reading skills. They identified that 48% of children with *emerging* language impairment (those whose language scores fell 1 SD below the mean at 8 but not 3.5 years of age) and 41% of those with *persisting* language impairment (those whose language scores fell 1 SD below the mean at 8 and 3.5 years) were reading at 1 SD below the mean by 8 years of age, compared to just 14% and 8% of children in *typical* and *resolving* language subgroups respectively.

Above, we have described recent studies examining the nature of language trajectories observed in children with typical and atypical development. We have seen that different types of language trajectories can be found at different ages, and that although children can be allocated successfully to trajectory subgroups, the heterogeneous nature of those subgroups means that their practical clinical relevance, especially in the preschool years, may be limited. It is worth acknowledging, however, that although trajectory subgroups may not enable exact predictions of children's subsequent development, they do at least provide a more complete picture of a child's abilities than a "snapshot" at a given point in time.

## *Risk factors and predictors for trajectory subgroup membership*

As noted earlier, the identification of language trajectory subgroups and the allocation of children to those subgroups are of interest both theoretically and clinically. Also of interest is the extent to which subgroup membership is associated with various risk factors and predictors, which may enable a more fine-grained or earlier allocation of children to subgroups. To this end, most research in this area has attempted, not only to identify trajectory subgroups, but also to identify the characteristic and differentiating features of those subgroups.

In a general sense, this research has shown that, when comparing children whose language is on a downward or consistently low trajectory with those on an upward or consistently typical trajectory, the children who are improving tend to have higher nonverbal cognition (Snowling et al., 2016), to come from families with higher socio-economic status (Ukoumunne et al., 2012), to have mothers who are more educated and have higher vocabulary scores (Ukoumunne et al., 2012), and to be more likely to come from a minority language background (McKean et al., 2017). On the other hand, a pattern of deteriorating language is associated with variables such as lower nonverbal ability, low birth weight, a diagnosis of learning disability, lower family literacy, incomplete paternal education, maternal smoking during pregnancy, fewer children's books at home, low family income, increased family risk of dyslexia, being male, and lower likelihood of a minority language background (Armstrong et al., 2017).

This summary makes clear the range of potential risks and protective factors that have been identified in studies of language trajectories in children with typical development. The majority are straightforward, although McKean et al.'s (2017) findings relating to the influence of a minority language background deserve brief comment. The data from their study indicate that some children with low early language skills were from a minority language background. These children were likely to catch up to their peers with prolonged exposure to the community language. On the other hand, some children with low early language skills were diagnosed with a learning disability, autism, or attention deficit hyperactivity disorder over the course of the

study (McKean et al., 2017). For these children, the negative impact of a developmental delay was likely to persist throughout the child's early years (McKean et al., 2017). Longitudinal results reported by McKean et al. (2015) for a separate sample of 883 participants support this view, in that children from a minority language background made the fastest rate of progress in language from 4 to 7 years of age.

## *Children with PCHL*

There are two reasons why the instability observed in children with normal hearing may not apply to children with PCHL. Firstly, current management of PCHL typically includes early fitting of devices (HAs or CIs), and early enrolment in speech and language intervention (Joint Committee on Infant Hearing, 2007, 2013). The age at which treatment commences has lasting effects on language development. Secondly, even though the early provision of HAs or CIs to increase audibility would offer the child with PCHL the opportunity of auditory access to sounds in the environment to support language development, the acoustic signal received via a CI, and to a lesser extent via a HA, is degraded in comparison with the naturally occurring signal. Furthermore, the presence of PCHL is associated with not only a reduction in sensitivity to sounds (which can be treated by early fitting of hearing devices), but also a decrement in the analytic ability of the impaired auditory system to process acoustic signals. The more severe the hearing loss, the poorer is the frequency and temporal resolution ability, and the less speech information could be extracted from a certain amount of audible signal. This is commonly referred to as hearing loss desensitization (Ching, Dillon, Katsch, & Byrne, 2001). Constraints due to changes in the acoustic signal provided via electric or acoustic stimulation (CI or HA respectively) and variations in the analytic abilities of the impaired auditory systems are likely to have significant effects on language growth across time.

The current literature suggests that language growth observed in children with PCHL appears to be more stable than that reported for children with typical hearing. Koehlinger et al. (2013) showed that children with HAs had poorer expressive language than their peers with normal hearing at 3 years, and there was no significant tendency for the difference between groups to increase or decrease with time when the children were assessed at 6 years of age. Yoshinaga-Itano, Baca, and Sedey (2010) reported on 87 children with normal cognitive ability but severe to profound hearing loss, using HAs or CIs. Assessments of receptive language and expressive vocabulary at 48 to 87 months of age were analyzed to examine language growth. On average, the children achieved age-appropriate language levels at ages 4 to 7 years, and demonstrated a mean rate of growth that was commensurate with chronological age. About 80% of the cohort maintained a constant rate of development. The authors concluded that this development is possible when children were implanted below 24 months of age. Leigh et al. (2013) compared the language outcomes of 35 children who received a CI before 12 months of age and 85 children who received a CI between 13 and 24 months of age. They found that the former group demonstrated age-appropriate language abilities at 3 years after implantation, whereas the group who received later implantation demonstrated a significant language delay. Tomblin et al. (2015) presented longitudinal analyses of language in children with mild to moderately severe hearing loss in a study that used an accelerated longitudinal design. Data collected from age 2 to 6 years showed that children with PCHL obtained scores that were within 1 SD of those of their peers with normal hearing. Degree of hearing loss and maternal education were associated with language levels. However, there was no significant effect of degree of hearing loss on language change across time (at least over the measurement range of ages).

## *Language growth in children participating in the LOCHI study*

The prospective nature of the LOCHI study provides an opportunity for examination of language change across time for children with PCHL. We examined the language outcomes of the same cohort using the PLS-4 at 3 and 5 years of age. Drawing on data from 224 children with hearing loss ranging from mild to profound, we examined language change across the two measurement time points, separately for children without or with additional disabilities. Figure 20.1 shows the language pathways for the two groups.

For children without additional disabilities, only 7.9% of those who attained language scores within the typical range (scores that were above −1 SD of the normative mean) at 3 years presented with low language (below −1 SD) at 5 years of age. Ninety-two percent of children who had typical language at 3 years also had typical language at 5 years of age, demonstrating language growth consistent with change in chronological ages. Of those who had low language

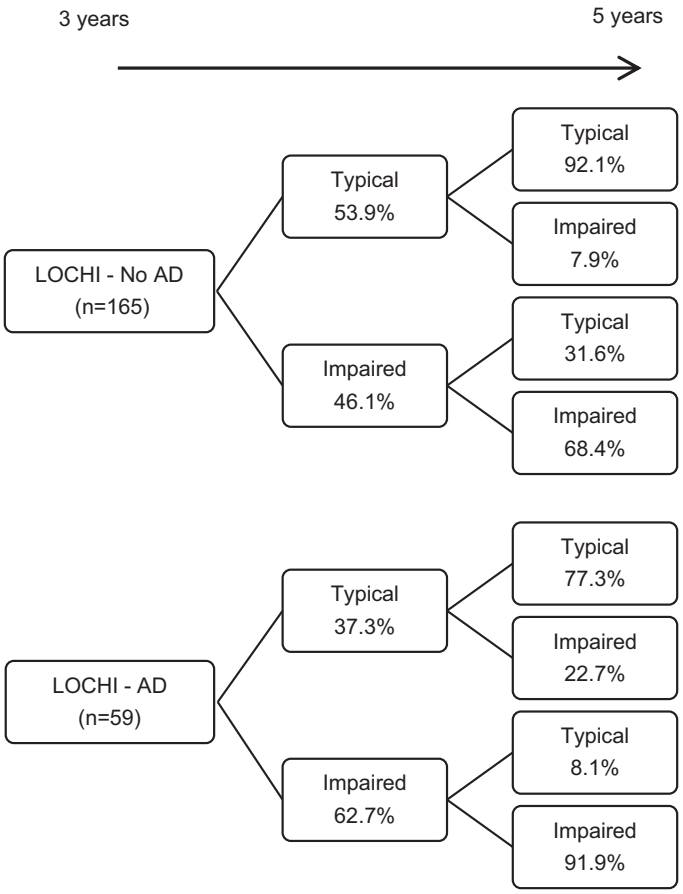



*Figure 20.1* Language pathways between 3 and 5 years of age in the LOCHI study. Children with or without additional disabilities (AD) are shown separately. "Typical" denotes standard scores that are ±1 SD of the normative population mean for standardized language tests (Preschool Language Scale, v4, total language scale, encompassing receptive and expressive language), and "Impaired" denotes standard scores that are below 1 SD of the normative mean.

at 3 years of age, one-third had age-appropriate language by 5 years of age, demonstrating a rate of language growth exceeding that of chronological age. Some of these children with severe or profound hearing loss had received CIs between the test intervals. This is consistent with findings reported by Yoshinaga-Itano et al. (2010) that found cochlear implantation to be associated with greater likelihood of "closing the language gap".

For children with additional disabilities, about a quarter of those who had typical language at 3 years of age had lower language at 5 years. About 8% of children with low language at 3 years achieved age-appropriate language levels at 5 years. Again, cochlear implantation was one of the factors explaining the rate of language growth. Those children whose additional disabilities did not entail developmental delays demonstrated language growth commensurate with their chronological age (Cupples, Ching, Leigh, et al., 2018).

## Summary of findings and implications

In summary, current evidence suggests:

1 Early fitting of HAs and CIs is effective in improving the language outcomes of children with PCHL, including those with additional disabilities.
2 Cognitive ability, degree of hearing loss, maternal education, use of speech in communication, and presence of additional disabilities also influence language outcomes.
3 The language development of children with PCHL from 3 to 5 years of age may present with greater stability than that observed in children with typical hearing.

Even though PCHL places children at risk for delays in language development, risks are moderated by the provision of early and consistent access to high-quality well-fitted HAs or CIs that optimize audibility. There is also a positive effect of early speech and language therapy that provide targeted prevention and intervention from the post-diagnostic period to the preschool years.

As language delays make a child vulnerable to later difficulties, and increasingly so when the young child moves to formal schooling (Law, Tomblin, & Zhang, 2008), it is important to tailor continual support to the needs of individual children with PCHL. Early monitoring of language outcomes may hold the key to the design of targeted programs to meet differential needs, so as to capitalize on the benefits attained through early provision of hearing devices and speech and language therapy services.

It would be useful to further explore the patterns of change at both a group and an individual level as children move through school to determine the impact of early language difficulties on educational attainment, social participation, and quality of life outcomes.

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# 21

# LANGUAGE ACQUISITION IN CHILDREN WITH AUTISM SPECTRUM DISORDER

*Calum Hartley*

## Background

Autism spectrum disorder (ASD) is a neurodevelopmental disorder defined by profound social deficits in conjunction with restricted and repetitive behavioral tendencies (American Psychiatric Association, 2013). Epidemiological data show that ASD affects approximately 1%–2% of children worldwide and is diagnosed more frequently in males than females (Elsabbagh et al., 2012). Although language impairments are not a core criterion for ASD, they are a very common feature and play a central role in specifying an individual's unique presentation (American Psychiatric Association, 2013). Professional assessments are often motivated by parental concerns about delayed language acquisition (De Giacomo & Fombonne, 1998), and a significant subgroup are minimally verbal throughout their lifetime (Pickles, Anderson, & Lord, 2014). These individuals often present with complex communication needs and intellectual disabilities that impact their cognitive development and independence (Fernell, Eriksson, & Gillberg, 2013). Understanding why so many children with ASD have difficulty acquiring language is a global research objective, and a vital precursor to the development of effective interventions.

The purpose of this chapter is to provide an up-to-date summary of several branches of research focusing on language in ASD. This chapter will briefly summarize the characteristics of language in autism, spotlight the profile of minimally verbal children, explore differences in lexical acquisition mechanisms, consider strategies for assessing language in children with ASD, and review recent advances in the development and implementation of evidence-based interventions.

## Language in autism: a brief overview

Delayed language production is a common, but not universal, characteristic of ASD (Gernsbacher, Morson, & Grace, 2015). Whereas typically developing (TD) children usually utter their first words by 12 months, children with ASD start to speak at 38 months on average, and only 30%–50% acquire phrase speech by 4 years (Ellis Weismer & Kover, 2015; Howlin, 2003). Children with ASD tend to have much smaller expressive vocabularies than TD children matched on chronological age (Charman, Drew, Baird, & Baird, 2003; Luyster, Kadlec, Carter, & Tager-Flusberg, 2008), and many produce unusual "echolalic" utterances (immediate or delayed

imitation of others' language) on a frequent basis (Tager-Flusberg & Calkins, 1990). However, in comparison to TD and language-delayed control groups (e.g. late talkers) matched on language production, children with ASD do not differ in terms of their most frequently used words (Ellis Weismer et al., 2011). Current estimates indicate that 70% of children with ASD are eventually able to communicate using fluent sentences, and approximately 10% demonstrate expressive language skills that are commensurate with their chronological age (Pickles et al., 2014).

Autism also impacts children's language comprehension. Most children with ASD understand fewer words than age-matched TD children, and many are relatively more impaired in receptive than expressive language (Luyster et al., 2007, 2008). Approximately 30% of preschoolers with ASD show an unusual linguistic profile characterized by almost-equivalent receptive and expressive abilities (Hudry et al., 2010), whereas TD infants' receptive skills significantly outweigh their productive skills in every communicative domain (Adamson, 1995). Almost all children with ASD have difficulty understanding pragmatics (i.e. how language is used for social purposes) irrespective of their general linguistic competencies (Kelley, Paul, Fein, & Naigles, 2006). This trait has been linked to general intellectual disabilities (Abbeduto & Hesketh, 1997), impaired Theory of Mind (Baron-Cohen, Baldwin, & Crowson, 1997), and deficits in executive functioning (Ozonoff et al., 2004). Yet, when matched to TD children on language comprehension, the composition of grammatical (e.g. nouns, verbs) and semantic (e.g. objects, animals) categories within their receptive vocabularies is not atypical (Charman et al., 2003). Furthermore, the acquisition of more advanced comprehension skills (e.g. understanding figurative language) by children with ASD appears to follow a normal trajectory in line with their receptive language development (Gernsbacher & Pripas-Kapit, 2012; Norbury, 2005).

Research exploring *how* individuals with ASD use morphology (individual units of meaningful language) and syntax (combinations of words into phrases) has yielded conflicting results. Tek, Mesite, Fein, and Naigles' (2014) growth curve analysis showed that the trajectories for morphosyntax and sentence complexity in TD children and verbal children with ASD are equivalent when differences in intercept are accounted for. In comparison to language-matched TD controls, children with ASD acquire Brown's 14 morphemes in a similar order (Brown, 1973), show minimal differences in sentence repetition and story-telling tasks, demonstrate similar understanding of wh-questions, and evidence similar use of plural and tense markers (Goodwin, Fein, & Naigles, 2012; Naigles, Kelty, Jaffery, & Fein, 2011; Waterhouse & Fein, 1982). By contrast, other studies have shown that children with ASD make more morphological errors than mental-age-matched control groups (Bartolucci, Pierce, & Streiner, 1980) and generate less syntactically complex spontaneous language (Eigsti, Bennetto, & Dadlani, 2007). Eigsti and Bennetto (2009) found that children with ASD were significantly less accurate at judging the correctness of sentence grammar than TD controls matched on age, IQ, and receptive vocabulary. It is also well documented that children with ASD make frequent errors when using pronouns (e.g. "I" and "me"; Lind & Bowler, 2009). Importantly, studies investigating variability within ASD have proposed the existence of at least two developmental profiles for spoken language; one characterized by largely intact morphosyntactic abilities, and another characterized by grammatical impairments (Roberts, Rice, & Tager-Flusberg, 2004; Tek et al., 2014). For more detailed and comprehensive reviews of language structure in ASD, see Eigsti, de Marchena, Schuh, and Kelley (2011), Boucher (2012), and Naigles and Tek (2017).

Overall, comparisons against language-matched controls suggest that global linguistic development in autism may be delayed rather than qualitatively deviant. Linguistic milestones are achieved via a trajectory that is broadly similar to non-autistic development, and for many individuals, specific deficits tend to resolve and stabilize at mental-age-appropriate levels (Gernsbacher et al., 2015; Boucher, 2012). In addition, evidence that language difficulties and autistic

traits are influenced by distinct genetic, environmental, and etiological factors implies that these domains may develop independently (Taylor et al., 2014). While language in ASD may have some unusual characteristics (e.g. atypical pronoun use, echolalia, absence of the normative advantage for receptive over expressive language), these features are not universal or necessarily unique to autism (Gernsbacher, Morson, & Grace, 2016). Indeed, language development in ASD is extraordinarily heterogeneous. At one end of the spectrum, a sub-set of children achieve age-appropriate scores on most standardized language assessments, but show subtle pragmatic anomalies in naturalistic interactions (Boucher, 2012). However, a sub-set of children at the other end of the spectrum struggle to learn any language, potentially due to deviant functioning of specific lexical acquisition mechanisms (as discussed later in this chapter).

## Minimally verbal children with autism

### *Description and prevalence*

A substantial proportion of children with ASD are "minimally verbal" (Tager-Flusberg & Kasari, 2013). The definition of "minimally verbal" is relatively broad, encompassing children who have absolutely no speech as well as those who use an extremely limited repertoire of words (5–20) for communicative purposes (Kasari, Brady, Lord, & Tager-Flusberg, 2013). Language use by these children tends to be infrequent, inflexible, echolalic, and context-specific. Minimally verbal children with ASD may attempt to communicate their instrumental needs, but their reliance on non-linguistic vocalizations and restricted speech sounds can hinder their caregivers' comprehension (Tager-Flusberg, Paul, & Lord, 2005). Difficulties communicating their needs and understanding others' communication can elicit frustration, causing children to display self-injurious behaviors and strike out aggressively, and inducing the development of behavioral rituals (Bondy & Frost, 2002).

It was historically estimated that around 50% of children with ASD would never develop functional phrase speech (Prizant, 1996; Rutter, 1978). However, recent literature indicates that this percentage could be decreasing. In a longitudinal study that tracked the language development of 96 children with ASD between 2 and 9 years, Anderson and colleagues (2007) reported that 29% of this population had no or few consistent words at final assessment. These children tended to have severely impaired joint attention skills early in childhood, indicating a connection between preverbal social cognition and later language outcomes (also see Yoder, Watson, & Lambert, 2015; McDuffie, Yoder, & Stone, 2005). More recently, Norrelgen et al. (2015) reported communication outcomes for 165 children with ASD aged 4 to 6.5 years. They sought to establish the proportion of children with profoundly impaired language acquisition, and explored the relationship between language and cognitive ability. The results showed that 15% of children were nonverbal, exhibiting expressive language age equivalents below 15 months with fewer than three spoken words. A further 10% were minimally verbal, with expressive language age equivalents below 24 months and the occasional use of two-word phrases. The vast majority of these children had severe intellectual disabilities, and nearly 75% had performance IQs below 50. In another recent study, Rose et al. (Rose, Trembath, Keen, & Paynter, 2016) documented the proportion of children with ASD who were minimally verbal upon entering and exiting a community-based early intervention program that lasted 5 years. Out of 246 children, 26% exited the program using fewer than five spoken words. Taken together, these contemporary statistics suggest that children with minimal-to-no spoken language comprise 25%–30% of the ASD population. This reduction in prevalence may be attributed to numerous factors, including

1. the broadening of diagnostic criteria, 2. increasing numbers of verbal children receiving diagnoses, and 3. increased access to early interventions (Tager-Flusberg & Kasari, 2013).

## *Minimally verbal or preverbal?*

Children are often categorized as minimally verbal if they do not acquire spoken language before 5 years (Tager-Flusberg & Kasari, 2013). However, some children who meet this criterion eventually develop functional and fluent language at a later stage of development. Thus, it may be that a child with significantly delayed language acquisition is "preverbal" rather than truly minimally verbal. Although preverbal children lack functional speech, they possess crucial pre-linguistic skills that ultimately scaffold functional language acquisition (DiStefano & Kasari, 2016). The early identification of children as preverbal or minimally verbal has important implications for intervention programs and prediction of later outcomes; however, accurate discrimination is hindered by extreme variability in linguistic development within ASD (DiStefano & Kasari, 2016).

Research has strived to identify factors that determine whether a nonverbal child will successfully develop language after receiving interventions (Kasari et al., 2013; Tager-Flusberg & Kasari, 2013). In comparison to peers who remain minimally verbal, preverbal children with ASD tend to use more basic gestures, produce more consonant sounds, imitate more frequently, and show increased joint attention (Ellis Weismer & Kover, 2015; Woynaroski, Yoder, & Watson, 2016). These foundational social-communicative abilities are known to statistically predict language outcomes in children who are identified as minimally verbal at a young age (e.g. Woynaroski et al., 2016). Several studies have reported that children with higher nonverbal IQs usually display superior linguistic skills, indicating a predictive relationship between language development and general cognitive functioning in ASD (Kjelgaard & Tager-Flusberg, 2001; Norrelgen et al., 2015). However, language impairments in minimally verbal children with ASD are often more severe than predicted based on their IQ (Lord, Risi, & Pickles, 2004), suggesting that linguistic heterogeneity in ASD cannot be attributed to variability in cognitive functioning exclusively. Promisingly, recent advances in neuroimaging research have revealed that minimally verbal and preverbal children may be distinguished based on brain structure and neural activity. Children with more positive language outcomes experience greater cortical activation in response to speech than children who remain minimally verbal (Kuhl et al., 2013; Lombardo et al., 2015). Minimally verbal children also show atypical structural development in brain regions associated with language development, including the left middle temporal gyrus and arcuate fasciculus (Riva et al., 2011; Wan, Marchina, Norton, & Schlaug, 2012). Importantly, these studies indicate that severe communication impairments exhibited by minimally verbal children may be caused by a fundamental deficit in language acquisition that is separable from their ASD diagnosis (i.e. co-morbid developmental language disorder; Tager-Flusberg & Joseph, 2003).

Despite their prevalence, minimally verbal children are often neglected in empirical research (Tager-Flusberg & Kasari, 2013). Studying children with profound language impairments is essential to advance and inform theoretical understanding of language acquisition mechanisms, highlight barriers to language learning, and inform the design and implementation of effective interventions (Eigsti et al., 2011). As linguistic milestones (e.g. age of first words and phrases) strongly predict developmental trajectories for speech and adaptive skills (Howlin, Goode, Hutton, & Rutter, 2004; Kover et al., 2016), investigating the nature and causes of severe language deficits in ASD is of clear intellectual and practical importance.

## Differences in lexical acquisition mechanisms

In order to generate effective interventions that promote language development in children with ASD, it is vital to understand which processes that support language acquisition are impaired or functionally atypical. Provision of an in-depth and comprehensive account of this expansive topic is beyond the scope of this chapter (see Arunachalam & Luyster, 2016, for a focused review), so we will concentrate on evidence from a few significant mechanisms: attentional preferences for speech, use of linguistic and social cues that facilitate the identification of word meanings, lexical retention, and the application of constraints that inform the generalization of words to novel category members.

### *Preferences for speech*

TD infants are born with an innate preference for speech over non-speech sounds (Vouloumanos & Werker, 2007; Shultz & Vouloumanos, 2010). They also prefer infant-directed speech (IDS), which is characterized by slower speed, greater pitch variation, simplified sentence structure, longer repetitive intonational structures, and higher frequency (Fernald, 1985; Gleitman, Newport, & Gleitman, 1984), over speech directed at adults. The strength of infants' preference for speech predicts lexical development (Vouloumanos & Curtin, 2014; Weisleder & Fernald, 2013), and IDS supports language learning by facilitating word segmentation (Floccia et al., 2016) and providing redundant cues to grammatical structure (Singh, Nestor, Parikh, & Yull, 2009). Conversely, children with ASD do not show reliable preferences for speech over non-speech sounds (Curtin & Vouloumanos, 2013), or IDS over adult-directed speech (Droucker, Curtin, & Vouloumanos, 2013). The absence of these preferences may have important consequences for language acquisition as they statistically predict speech comprehension and production in children with ASD both concurrently and longitudinally (Paul, Chawarska, Fowler, Cicchetti, & Volkmar, 2007; Watson, Baranek, Roberts, David, & Perryman, 2010). Although diminished preference for IDS may characterize ASD at a group level, and potentially represent an early diagnostic marker (Filipe, Watson, Vicente, & Frota, 2017), there is considerable heterogeneity across individuals, and further research is required to fully understand the causes and consequences of this deficit (Droucker et al., 2013).

Infants are immersed in a world of language from birth, and the experience of listening to speech narrows their auditory perception so they become attuned to their native language (Kuhl, Williams, Lacerda, Stevens, & Lindblom, 1992). In their classic study, Werker and Tees (1999) demonstrated that infants are capable of discriminating speech sounds from native and non-native languages with similar accuracy until approximately 8 months. However, by 10 months, infants' sensitivity to non-native sounds decreases, while their discriminatory perception of native sounds is retained. By contrast, heightened perception of sounds over the lifetime is a common trait in ASD (Jones et al., 2009). In comparison to controls, children and adults with ASD show increased sensitivity and accuracy when categorizing pitch and discriminating auditory stimuli including word pairs, lexical tones, pure tones, nonwords, and non-speech sounds (Bonnel et al., 2010; Heaton, Hudry, Ludlow, & Hill, 2008; Järvinen-Pasley, Wallace, Ramus, Happé, & Heaton, 2008). It is possible that generally heightened auditory sensitivity has a negative effect on early language acquisition, as the perceptual system may not specialize to the sounds of one's native language (Kuhl et al., 2008). Indeed, evidence suggests that children with ASD with superior discrimination of auditory frequencies are more likely to be delayed in speaking their first words (Bonnel et al., 2010; Jones et al., 2009). This may be because perceptual attuning to language facilitates the detection of word boundaries and syntactic structures,

and enhanced auditory sensitivity inhibits the efficiency of these abilities (Eigsti & Fein, 2013). Thus, it could be that language delay or impairments in ASD result from failure of the auditory perceptual system to functionally or structurally specialize in processing speech during infancy.

## *Identifying meaning: mutual exclusivity and social cues*

To learn and use language, children must establish lasting relationships between discrete phonological patterns – words – and their associated semantic categories. Once a spoken word has been identified by the auditory perceptual system, the process of mapping to meaning involves several mechanisms: 1. *referent selection*; identification of a word's intended meaning, 2. *retention*; storage of the word-referent pairing in long-term memory enabling later retrieval, and 3. *generalization*; appropriate extension of the word to new category members. Below we will review research that has investigated the integrity of these processes in ASD.

The "dynamic associative account" (McMurray, Horst, & Samuelson, 2012) – a leading theory of neurotypical word learning – posits that referent selection and retention are underpinned by separate fast and slow learning mechanisms. In the context of the naming event, referent selection (fast mapping) requires solving the problem of referential ambiguity (there are often multiple potential targets for a newly heard word; Quine, 1960) and involves narrowing children's attention down to a single target (the intended referent). This attentional narrowing can be directed by numerous sources of information, including universal linguistic constraints. One such constraint is "mutual exclusivity" (ME), the assumption that a given word has only one referent (Markman, 1990). By 2 years of age, TD children apply ME to assign novel words to unfamiliar objects when presented alongside familiar objects with known names (Carey, 1978; Markman & Wachtel, 1988). Several studies investigating the use of ME by children with ASD suggest that this heuristic is intact and employed by individuals across the spectrum. Preissler and Carey (2005) presented minimally verbal children with pairs of pictures and objects – one familiar and one unfamiliar – and asked them to identify the referent of a novel word. The participants spontaneously applied ME by mapping the novel name to the unfamiliar object on 82% of trials. In a study by de Marchena, Eigsti, Worek, Ono, and Snedeker (2011), high-functioning children with ASD were presented with two unfamiliar objects. One object was ostensively named, and children were asked to identify the referent of a second novel word. Participants correctly identified the unnamed object as the referent of the second novel word on approximately 90% of trials, thus demonstrating effective use of ME (also see Parish-Morris, Hennon, Hirsh-Pasek, Golinkoff, & Tager-Flusber, 2007). Studies have found that other heuristics, such as the noun bias (the tendency to map novel words onto objects rather than actions), are also intact in ASD (Swenson, Kelley, Fein, & Naigles, 2007). Together, these findings present convincing evidence that children with ASD, including those with severe linguistic and cognitive impairments, can accurately identify the referents of newly heard words based on lexical assumptions.

TD children also utilize social-pragmatic cues to solve the problem of referential ambiguity. From an early age, TD infants are aware that a novel word is likely to refer to whatever object is currently the focus of a speaker's attention (Bloom, 2002) and spontaneously infer referential intent from gaze, gestures, and emotional affect (Baldwin, 1993; Nappa, Wessel, McEldoon, Gleitman, & Trueswell, 2009; Tomasello, Strosberg, & Akhtar, 1996). Baldwin's (1991) seminal study revealed that TD infants aged 16–19 months will spontaneously consult a speaker's face when they hear a novel word and identify a referent based on their direction of gaze. However, children must be sensitive to social cues if they are to inform language acquisition. It is traditionally argued that word learning deficits in ASD stem from diagnosis-defining impairments in social communication (e.g. Baron-Cohen et al., 1997). Children with ASD show population-level

impairments in intention reading (Griffin, 2002; Hartley & Allen, 2014a, 2015a), eye contact and social orienting (Nadig, Ozonoff, Young, Rozga, Sigman, & Rogers, 2007; Osterling, Dawson, & Munson, 2002), gaze following (Gillespie-Lynch, Elias, Escudero, Hutman, & Johnson, 2013), and joint attention (Mundy, Sigman, & Kasari, 1990). Based on evidence that these abilities statistically predict concurrent and longitudinal language outcomes in ASD (Anderson et al., 2007; McDuffie et al., 2005), it has been theorized that language acquisition may depend on the severity of social-communicative deficits (Thurm, Lord, Lee, & Newschaffer, 2007).

Perhaps surprisingly, studies investigating whether children with ASD are sensitive to social cues when identifying word referents report mixed findings. An early study by Baron-Cohen et al. (1997) discovered that children with ASD and profound language impairments mapped novel labels onto objects that were the focus of *their* attention, rather than a speaker's intended referents. By contrast, ability-matched TD children and intellectually disabled children utilized the speaker's direction of gaze as a cue to mapping. Preissler and Carey (2005) replicated Baron-Cohen's findings with another sample of minimally verbal children with ASD. In a more recent study, Gliga et al. (2012) found that linguistically impaired children with ASD could follow gaze to the correct referents of words, but then failed to map word-referent relationships. These results suggest that word learning in language-impaired children with ASD is not informed by cues to a speaker's referential intent.

On the other hand, studies with high-functioning samples suggest that children with ASD *do* attend to social cues when identifying word meanings. Employing the same paradigm as Baron-Cohen et al. (1997), Luyster and Lord (2009) found that young children with ASD and TD children matched on vocabulary and verbal mental age (approx. 2 years) did not significantly differ on their use of social cues when mapping novel word-referent relationships. In McGregor and colleagues' study (McGregor, Rost, Arenas, Farris-Trimble, & Stiles, 2013), children with ASD and TD controls matched on chronological age and nonverbal IQ watched a video of an adult speaking an unfamiliar word while positioned in front of three unfamiliar objects. When the adult directed her gaze at the intended referent, children with ASD and TD controls mapped the word correctly on 74% and 73% of trials respectively (also see Norbury, Griffiths, & Nation, 2010). Another study by Bean Ellawadi and McGregor (2016) investigated whether children with ASD would follow an experimenter's gaze to map new word-object relationships over multiple trials. In comparison to TD controls matched on receptive vocabulary, few children with ASD attended to gaze on the first trial. However, across several trials, the populations did not differ on their attendance to gaze or their fast mapping accuracy.

In light of growing evidence, it is now widely argued that children with ASD who develop functional language skills are sensitive to social-communicative cues when learning words in laboratory environments. However, it is unclear to what extent children's sensitivity to social cues in highly controlled settings translates to naturalistic word learning. It has recently been argued that social cues facilitate word learning insofar as they direct children's attention to referent objects and away from competitors, thus increasing the accuracy of associative learning mechanisms, rather than providing a window to the speaker's referential intentions (Axelsson, Churchley, & Horst, 2012). Children with diminished social motivation may not reliably attend to gaze or gestural cues when deciphering the meanings of words in natural learning environments (Chevallier, Kohls, Troiani, Brodkin, & Schultz, 2012), or they may be distracted or overwhelmed by alternative sensory input. In support of this hypothesis, Tenenbaum, Amso, Righi, and Sheinkopf (2017) found that holding a target object near a speaker's mouth facilitated learning in children with ASD, whereas holding the object far from their mouth hindered performance (children's attention was divided between the two features of the visual scene, reducing the strength of the encoded word-referent association). In addition, Akechi and colleagues

(2011) found that children with ASD aged 6–12 reliably mapped a novel word to a speaker's object (the intended referent) only when it was more perceptually salient than an object they themselves were holding.

Overall, the balance of evidence suggests that referent selection is not pervasively impaired in ASD, and therefore cannot account for severe language acquisition difficulties. However, minimally verbal children with ASD (and possibly more verbal individuals) may not use social cues to disambiguate unfamiliar word meanings in natural contexts, therefore increasing their dependency on lexical heuristics (e.g. ME) and consequently raising the probability of mapping errors.

## *Retention*

Although referent selection may be functional in ASD, it is important to acknowledge that correct mapping-to-meaning does *not* constitute word learning. Horst and colleagues have repeatedly demonstrated that TD children forget new words just 5 minutes after performing at ceiling on a referent selection task (Horst & Samuelson, 2008; Horst, Scott, & Pollard, 2010; Axelsson et al., 2012). This suggests that long-term word learning is the result of a separate mechanism. According to dynamic associative theory, word retention (slow learning) is underpinned by basic learning mechanisms that are highly sensitive to cross-situational statistics (McMurray et al., 2012). Over multiple learning instances, children gradually accumulate knowledge of how words map onto objects or actions in their environment. As children's referent selection skills develop with age, they experience more precise word-referent activation patterns that increase the accuracy and speed of learning (McMurray et al., 2012).

To date, lexical retention in ASD has received relatively little attention in comparison to referent selection. However, a small number of studies suggest that children with ASD may have specific difficulty retaining word-referent relationships. Evidence from Bedford et al. (2013) indicates that this deficit could relate to broader social-communicative impairments. In their study, TD 2-year-olds' retention of newly learned word-referent relationships significantly improved when they received corrective and reinforcing social feedback. By contrast, retention in 2-year-olds at high risk of developing ASD did not benefit from social feedback, and this deficit was associated with smaller receptive vocabularies. The authors propose that failure to learn from social input may inhibit vocabulary development in children who develop ASD. On the other hand, Norbury et al. (2010) reported that high-functioning children with ASD could retain word-object mappings as accurately as TD controls; however, they remembered significantly less semantic information about referents over time. Another possibility is that ASD impairs children's ability to track cross-situational relationships between words and their referents over time and contexts. While recent studies suggest that ASD does not affect statistical learning when processing visual stimuli (Roser, Aslin, McKenzie, Zahra, & Fiser, 2015) or segmenting speech streams (Obeid, Brooks, Powers, Gillespie-Lynch, & Lum, 2016), the ambiguity and complexity inherent in vocabulary development may place unique strain on associative learning mechanisms. In one study that has investigated cross-situational word learning in ASD, McGregor and colleagues (2013) found this ability to be impaired in children with significant language deficits. In sum, future research should explore the possibility that language-impaired children with ASD have a specific deficit in lexical retention following referent selection.

## *Generalization*

To use language flexibly, children must learn how to appropriately generalize words to previously unseen members of the same semantic category. TD children begin encoding word-referent

relationships at approximately 6 months (Friedrich & Friederici, 2011), and the majority of the earliest-acquired words refer to object categories that are well organized by shape (Samuelson & Smith, 1999; Perry & Samuelson, 2011). As children map a particular noun to additional category members, they quickly realize that every "X" is "X-shaped" (Samuelson & Smith, 1999; Smith, Jones, Landau, Gershkoff-Stowe, & Samuelson, 2002). By approximately 24 months, TD children infer the higher-order rule that noun-referent relationships are constrained by shape, and thus generalize newly learned words to novel objects based on this feature, rather than other perceptual properties (e.g. color, size, texture; Landau, Smith, & Jones, 1988). The emergence of this "shape bias" coincides with children's acquisition of approximately 50–150 count nouns (Gershkoff-Stowe & Smith, 2004; Samuelson & Smith, 1999), suggesting a link to statistical regularities in children's early vocabularies. Smith and colleagues (2002) propose that the process of learning object names selectively tunes children's attention to shape, which in turn accelerates their acquisition of new object names. The shape bias is underpinned by categorization – the cognitive process that organizes information into conceptual groups and enables the evaluation of new information based on existing concepts (Klinger & Dawson, 2001). TD infants group objects through the abstraction of prototypes which represent the "central tendency" of categories (Younger, 1990). If the global shape of a newly encountered object (e.g. a Porsche 911) is sufficiently similar to a stored prototype (e.g. the car basic-level category), a child may extend the label for that prototype (e.g. "car") to the unfamiliar entity (Son, Smith, & Goldstone, 2006).

It is well documented that children with ASD struggle to generalize information and behaviors across different contexts (Happé & Frith, 2006). This difficulty may also manifest in the extension of verbal labels to novel referents. Using a preferential looking paradigm, Tek and colleagues (Tek, Jaffery, Fein, & Naigles, 2008) tested whether children with ASD aged 2 to 3 years evidenced an attentional bias to shape over 12 months. Children viewed an unfamiliar object before being presented with two test objects (a target that matched the first object on shape but not color, plus a foil that matched on color but not shape). In "naming trials", the first object was assigned a novel label, and children were asked to identify which test object was also a referent of the word. Despite developing sizeable vocabularies over the year (exceeding 100 count nouns), children with ASD did not show preferential looking towards the shape-match test object. By comparison, TD participants matched on expressive language looked significantly longer at the shape-match once they had acquired 50 count nouns in their productive vocabularies. In a follow-up investigation employing the same task, Potrzeba, Fein, and Naigles (2015) tested larger samples over 20 months. Again, they found that children with ASD did not extend novel words based on shape at any stage, whereas TD controls evidenced a shape bias at the initial assessment (aged 20 months). The results from these two studies indicate a dissociation between vocabulary size and the maxims governing word learning in ASD. In a study by Hartley and Allen (2014b), language-impaired children with ASD were taught the name for an unfamiliar picture, and then sorted pictures and objects according to whether they were also referents of the newly learned label. The analyses showed that children with ASD extended labels to items that matched depicted objects on shape *and* color, but also frequently generalized to items that matched on only shape *or* color. Conversely, TD children matched on receptive vocabulary only extended labels to items that matched the depicted referent's shape. Although two studies suggest that shape-based label extension is unimpaired in high-functioning individuals (McGregor & Bean, 2012), or when verbal mental age exceeds 4.5 years (Field, Allen, & Lewis, 2016), it may be that early lexical development for many children with ASD is hindered by the absence of a shape bias.

Hartley and Allen (2014b) speculate that atypical label generalization by children with ASD could be related to differences in visual processing and prototype formation. ASD is often characterized by a preference for processing visual information at a local, rather than global, level

(Happé & Frith, 2006; Mottron, Dawson, Soulières, Hubert, & Burack, 2006). Hypersensitivity to local perceptual details may inhibit the filtering of category-irrelevant information and impact the abstraction of prototypes derived from global shape (Hartley & Allen, 2014b). Consequently, children with ASD may not identify shape as the perceptual constraint that organizes word-referent categories, thus inhibiting the emergence of the shape bias. No studies to date have attempted to "train" the shape bias in children with ASD, but research with TD infants suggests this could be possible: Smith and colleagues (2002) successfully evoked the shape bias, plus a surge in productive vocabulary development, in 17-month-old infants after 8 weeks' play-based training that involved naming unfamiliar objects. Children with ASD may require multiple experiences with a variety of category members in order to generate explicit "rules" that correctly define category membership (Klinger & Dawson, 2001). As such, it might be possible to teach a "shape-bias rule" by ostensively mapping the same name to differently colored examples of an object type (e.g. red, blue, and yellow cars), highlighting the fact that shape – rather than color – defines category membership (e.g. "car") and potentially prompting shape-based generalization to additional exemplars (e.g. green cars; Allen, Hartley, & Cain, 2015, 2016; Twomey, Ranson, & Horst, 2014). Exploring the efficacy and benefits of such training would be an interesting topic for future research.

In summary, language acquisition in ASD may be delayed or inhibited by the absence or impairment of fundamental mechanisms that support early learning. At a group level, children with ASD show atypical auditory perception and diminished preferences for speech (e.g. Bonnel et al., 2010; Curtin & Vouloumanos, 2013), and individuals with linguistic deficits show limitations in their lexical referent selection, retention, and generalization (Gliga et al., 2012; Norbury et al., 2010; Potrzeba et al., 2015). However, language in ASD is characterized by exceptional heterogeneity, and the severity of differences associated with each mechanism can vary tremendously between individuals.

## Language assessments and interventions

### *Assessing language in ASD*

Assessing the language abilities of children with ASD is a vital component of research and applied practice. Academics assess their participants' language skills for many important reasons, including sample characterization and population matching, exploration of developmental mechanisms, and identification of relationships between language and other cognitive domains. Practitioners and interventionist researchers utilize language assessments for monitoring the effects of treatments, and screening for ASD often involves testing whether a child has reached developmental milestones for receptive and expressive language (Johnson & Myers, 2007). To obtain an accurate account of children's language abilities it is recommended that professionals utilize a range of measures (Kasari et al., 2013). Natural language samples recorded during interactions with caregivers or practitioners are an excellent vehicle for assessing multiple aspects of children's expressive language (e.g. pragmatics, phonological repertoire, grammar, lexical knowledge, etc.). Sample duration should be at least 30 minutes (possibly collected across multiple situations), thus ensuring a rich representation of the child's linguistic profile (Miller & Chapman, 2000). The analysis of natural language can be automated via audio recording technologies (such as the Language Environment Analysis (LENA) system) that encode specific sounds and features of speech, enabling the characterization of children's language-learning environments (Warren, Gilkerson, & Richards, 2010). Parent-report assessments (e.g. questionnaires and interviews) are a useful way of gleaning information that is difficult to assess directly, although there is a risk that

estimates of ability or impairment may be exaggerated (Tager-Flusberg et al., 2009). Conversely, psychometric tests enable the direct measurement of linguistic skills in comparison to standardized norms. When selecting standardized tests, assessors should seek measures with high reliability and validity that are appropriate for the developmental level of their sample (Tager-Flusberg et al., 2009). While reporting group-level descriptive statistics (e.g. mean raw scores or age equivalents) is an efficient and popular method of characterizing a sample, this approach does not accurately represent variability between individuals with ASD (Charman et al., 2003). Referring to "spoken language benchmarks" (e.g. use of preverbal communication, utterance of first words, use of word combinations, sentences, and complex language; Tager-Flusberg et al., 2009) or conducting item-level analyses (Rose et al., 2016) may be more effective ways of capturing within-sample variability. Regardless of how language is assessed, it is important to reflect on how findings from a sample generalize to the wider ASD population. Researchers should be mindful that some linguistic difficulties may be associated with certain developmental profiles (e.g. nonverbal or minimally verbal), but not others (e.g. phrase speech or complex language), and exploring individual differences presents an opportunity to identify predictive or precursory factors (Eigsti et al., 2011).

At a practical level, ASD can present a range of challenges when assessing language. Children with ASD often demonstrate attentional and motivational problems that affect their engagement (Eigsti et al., 2011; Koegel, Koegel, & Smith, 1997), and the tendency to perseverate when responding can reduce an assessment's accuracy (Waterhouse & Fein, 1982). As discomfort in an unfamiliar testing context can also impact validity and reliability, the assessment should be tailored to the child's needs (e.g. by preparing children in advance, including breaks, and utilizing reinforcers; Kasari et al., 2013). Measuring language in minimally verbal children via standardized tests brings additional problems; difficulties comprehending an experimenter's instructions and the inability to generate verbal responses often lead to floor effects (DiStefano & Kasari, 2016; Kasari et al., 2013). Some assessments such as the Peabody Picture Vocabulary Test (Dunn & Dunn, 2004), the British Picture Vocabulary Scale (Dunn et al., 2009), the Expressive One-Word Picture Vocabulary Test (Martin & Brownell, 2011), and the Mullen Scales of Early Learning (Mullen, 1995) are appropriate for testing children with ASD (including minimally verbal individuals) thanks to their visual scaffolding and/or accommodation of nonverbal responding. However, the standardized norms for these language assessments are based on TD samples, and children with ASD may have difficulties on certain test items (Bruckner, Yoder, Stone, & Saylor, 2007). For example, the receptive abilities of children with ASD may be underestimated by comprehension assessments that rely on social-communication skills (e.g. social orienting, pointing, joint attention). Many researchers favor parent-report measures such as the MacArthur-Bates Communicative Development Inventory (Fenson, Marchman, Thal, Reznick, & Bates, 2006) and the Vineland Adaptive Behavior Scales (Sparrow, Cicchetti, & Balla, 2005) because they cover development from birth, and their data are representative of children's communication in natural and familiar contexts (Kasari et al., 2013). These indirect assessments are very cost-efficient (particularly if resources, including qualified test administrators, are scarce) and provide a convenient means of acquiring initial information about a child's linguistic profile, but may lack the required sensitivity to detect effects in intervention studies (McConachie et al., 2015). For further information about assessments, see McConachie and colleagues' (2015) systematic review of measures that are often used in autism research.

## *Language interventions for children with ASD*

As the most positive longitudinal outcomes tend to be observed in children with ASD who have functional speech before 5–6 years (Baghdadli et al., 2007), the development of expressive

language is a vital priority for early interventions. Studies in the 1960s and 1970s revealed that children with ASD could successfully acquire new skills, including language, via intensive interventions based on "applied behavior analysis" (ABA) (Ferster & DeMyer, 1962; Risley & Wolf, 1967). ABA's core rationale is that human behavior can be modified by environmental influences, typically through operant conditioning (i.e. reinforcement of stimulus-response relationships; Lovaas et al., 1980). ABA interventions often employ "discrete trial training" (DTT); the deconstruction of target skills into isolated components that are taught individually in a sequence (e.g. imitating producing a word, followed by learning its meaning). While highly structured ABA interventions are popular with policy decision makers (McGrew, Ruble, & Smith, 2016; Kasari & Smith, 2016), they have drawn criticism for promoting context-specific learning, inhibiting spontaneity, being over-dependent on prompts and situational scaffolding, and eliciting high frequencies of challenging behaviors during training (Schreibman et al., 2015).

The focus of recent research has shifted towards "naturalistic developmental behavioral interventions" (NDBIs) that integrate ABA techniques with theories from developmental psychology (for an extended review, see Schreibman et al., 2015). NDBIs are informed by prominent concepts of early psychological development including: 1. children's development unfolds sequentially within and across domains (Piaget, 1966), 2. children can acquire skills located in the "zone of proximal development" (i.e. just beyond their current state;Vygotsky, 1978), and 3. learning is most effective when it is developmentally meaningful (Bruner, 1983) and children are actively engaged (Gibson, 1973). NDBIs are integrated into naturally occurring activities (e.g. play, transition, meal time) and across various environments (e.g. home, school, shops) that children experience as part of their daily routine. Employing multiple instructors (e.g. therapists, teachers, parents) and diverse materials, NDBIs enable children to develop a range of abilities in a holistic fashion, rather than targeting specific skills in isolation. As the complexity of natural learning experiences increases over time, children may develop more sophisticated skills (e.g. expressive language) on top of foundational precursors (e.g. nonverbal social cognition). Crucially, the need to explicitly teach isolated skills in multiple contexts is diminished by situating learning in dynamic social interactions with naturally occurring relationships between children's responses and rewards (McGee et al., 1985). Schreibman and colleagues (2015) highlight several benefits of NDBIs including increased generalization of behaviors, improved spontaneity, habituation to mundane distractions in everyday environments, more efficient and natural language acquisition, and superior gains in social development.

Many field-leading experts argue that NDBIs "represent state-of-the-art treatment" for young children with ASD (Schreibman et al., 2015, p. 2420). This claim is supported by evidence that NDBIs administered with high fidelity in clinics, in schools, and at home yield consistently positive outcomes for social communication (Wetherby et al., 2014; Shire et al., 2017) and potential benefits for language (Kasari, Paparella, Freeman, & Jahromi, 2008). One NDBI that has undergone extensive empirical investigation, and is designed to promote language acquisition, is Joint Attention Symbolic Play Engagement and Regulation (JASPER; Kasari et al., 2006). The premise of JASPER is to develop foundational nonverbal skills that scaffold later language acquisition (Charman et al., 2005). In an early study by Kasari, Freeman, and Paparella (2006), 58 children with ASD aged 3–4 years with receptive and expressive language age equivalents around 20 months were randomly allocated to a NDBI condition that targeted joint attention or symbolic play, or a control group that received highly structured ABA treatment as usual. In the NDBI conditions, child-driven play-based sessions lasting 30 minutes were administered daily for 5–6 weeks. At the end of treatment, children in the NDBI conditions improved in joint attention or symbolic play (depending on the targeted skill) to the extent that they were significantly superior to children in the control condition. Benefits in these domains were observed

in both structured assessments and naturalistic interactions with caregivers, indicating successful generalization of acquired skills across contexts. When participants were re-assessed at 6 and 12 months post-intervention, those in both NDBI conditions had improved their expressive language skills by 2.1–2.3 standard deviations (in comparison to 1 SD in the control group; Kasari et al., 2008). At 5 years post-intervention, sophistication of play at 3–4 years predicted whether children were functionally verbal. For those children who had functional speech at 8 years, expressive vocabulary was predicted by age of entry into the study (the earlier the better), assignment to the NDBI conditions, joint attention, and play. Gulsrud and colleagues' (Gulsrud, Hellemann, Freeman, & Kasari, 2014) analyses of developmental trajectories revealed that children who pointed most often at 3–4 years had superior expressive language at follow-up. Together, these findings indicate a causal link between early social-communication skills and later language outcomes in ASD, and suggest that this relationship can potentially be fostered by NDBIs.

While empirical support for NDBIs is building, it is important to note that their long-term effects on language acquisition require further investigation. Many intervention studies focus on short-term outcomes, which tend to reveal few significant differences between approaches. For example, Hampton and Kaiser's (2016) recent meta-analysis of 26 studies including 1738 participants with ASD (aged 3.3 years on average) reported that children's short-term language outcomes are only reliably affected by *who* administers the intervention (treatments that are parent-only or clinician-only are less effective than those administered by parents *and* clinicians). Across studies, children showed modest improvements in spoken language (equivalent to a few points on a standardized assessment) immediately after receiving experimental interventions, but the authors acknowledge that such small effects may not be clinically meaningful. Longitudinal findings from NDBI studies such as Kasari et al. (2008) are certainly promising, but the field would benefit from more intervention studies with rigorous designs (e.g. randomized controlled trials) reporting long-term outcomes in speech production and comprehension. This need is particularly pressing given the general resilience of children with ASD to interventions targeting language development, despite making gains in other aspects of social communication and symptom reduction (e.g. Pickles et al., 2016). Furthermore, it should be emphasized that the effects of any given intervention will be substantially impacted by the extreme heterogeneity that characterizes ASD. It is therefore vital that future research seeks to identify the factors that influence the effectiveness of specific interventions for children with specific developmental profiles (Kasari & Smith, 2016).

## Conclusions

Severely impaired language acquisition and usage are common characteristics of ASD (Eigsti et al., 2011). Although the majority of individuals develop fluent expressive language, approximately 25%–30% have little or no functional speech during childhood (Anderson et al., 2007). ASD has been shown to impact important mechanisms that support language acquisition. At the population level, children with ASD have diminished preference for speech and atypical perceptual tuning to language (e.g. Filipe et al., 2017), and minimally verbal children have difficulty learning and understanding the meanings of words (e.g. Hartley & Allen, 2014b, 2015b). The children who experience the greatest difficulty acquiring language tend to have more severe intellectual disabilities (Norrelgen et al., 2015) and greater abnormalities in brain structure and activation (e.g. Wan et al., 2012) than verbal peers. Development of expressive language in ASD is also strongly tied to early social communication, with superior skills in joint attention and symbolic play predicting greater linguistic outcomes concurrently and longitudinally (Luyster et al., 2008). While individuals with good verbal skills may be sensitive to social cues when

learning words (at least in laboratory environments; Ellawadi & McGregor, 2016), minimally verbal children have difficulty utilizing gaze and joint attention when mapping novel word-referent relationships (Preissler & Carey, 2005). Growing evidence suggests that NDBIs that integrate ABA principles with developmental theory represent a promising approach to targeting impairments in socialization and communication (Schreibman et al., 2015). By fostering the development of social-communicative precursors, NDBIs may also be effective at promoting language acquisition (Kasari et al., 2008), but more data concerning long-term outcomes are required to draw reliable comparisons to other approaches (e.g. highly structured DTT). Looking forward, it is vital that research continues to explore fundamental linguistic impairments in ASD to refine theoretical knowledge and inform the development of increasingly effective treatments. Further research is required to isolate the mechanisms that cause linguistic heterogeneity in ASD, and to identify the optimal environmental conditions that support language learning and development for children with different linguistic profiles.

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## SECTION 4

# Language acquisition in everyday situations



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# 22

# YOUNG CHILDREN'S WORD LEARNING THROUGH OVERHEARING

## Next steps

*Nameera Akhtar, Jackson Tolins, and Jean E. Fox Tree*

When we ask undergraduate students "How do you think a young child learns a new word?" they usually say something like "You hold up an object and say its label while the child is looking at it, and repeat the word a few times". This is regarded as a typical word-learning situation – an adult explicitly labeling an object for a child who is jointly attending to that object with that adult (see Chapter 11, this volume). But this type of direct teaching cannot be the whole story; in some cultural contexts, infants and toddlers experience very few didactic (and relatively few dyadic) interactions, but they certainly do learn words (Cristia, Dupoux, Gurven, & Stieglitz, 2017; Lieven, 1994). In contexts where there is less emphasis on direct teaching, adults tend to *expect* children to learn through observation (Rogoff, 2003). In fact, the ways Western adults teach and test the vocabulary of very young children seem very strange to adults in those cultural contexts: asking questions with known answers, such as "What's that called?" is an activity rooted in highly schooled cultures (Rogoff, Correa-Chavez, & Cotuc, 2005). The ways of interacting with young children that we generally view as "typical" – teaching and testing – may be related to experience with the institution of formal schooling. Parents who have been to school and who expect their children to go to school tend to interact with children in teacher-like ways (Rogoff et al., 2005).

Because researchers have a great deal of experience with schooling, we tend to emphasize teaching interactions when we study young children's learning. Many years ago, Bandura (1962) highlighted the importance of observational learning in early social development. But in the field of early language development, far more attention has been paid to child-directed speech than to the third-party conversations that take place within the hearing of young children. There are obvious practical reasons for this – it is far easier to record and transcribe child-directed speech, and harder to know if children are attending to the language spoken around them – but a cultural bias emphasizing didactic and dyadic interactions between adults and children may also play a role.

Recently, however, there has been an explosion of empirical studies of what is variously called *third-party learning*, *learning through overhearing*, or simply *observational learning*. These all involve contexts in which no one is directly teaching children or even talking to them; rather, children simply observe a third-party interaction. In these studies, there is no eye contact and no

communication between the learner and those being observed. In this chapter, we focus on those studies in which 1. the participants are very young children (toddlers and preschoolers) and 2. the outcome measure is word learning. For the purposes of this chapter, we define overhearing as occurring when children are listening in on a conversation, but not participating in it. We begin by examining why it is important to study word learning through overhearing, and then provide an overview of current findings before turning to directions for future research in this area.

## Why study learning through overhearing?

There are both theoretical and practical implications of children's ability to learn through overhearing. Theoretically, there are implications for the role of joint attention in early word learning (e.g., Baldwin, 1995; Tomasello, 1995) and for the theory of *natural pedagogy* (Gergely & Csibra, 2011), with its emphasis on didactic interactions and child-directed speech. Practically, there are implications for those who wish to facilitate language learning in special populations (Luyster & Arunachalam, 2018).

Joint attention is generally defined as two people coordinating attention to a thing/event with attention to each other, while maintaining awareness of their mutual focus. Traditionally, joint attention is operationalized by gaze alternation between the object of shared attention and the interlocutor. As overhearing involves situations in which children are not engaged with the speaker(s), learning through overhearing involves children learning without engaging in joint attention. While some theorists have argued for the crucial role of joint attention in early word learning, young children's ability to learn words through overhearing suggests one of two things: 1. that joint attention is not necessary for early word learning (Akhtar, 2005a); or 2. that joint attention can be manifested in multiple ways (Akhtar & Gernsbacher, 2007; Benigno, Clark, & Farrar, 2007).

Similarly, the theory of natural pedagogy privileges ostensive communication in the learning of "opaque cultural knowledge that is not (or not fully) comprehensible for the naïve observational learner" (Gergely & Csibra, 2011, p. 127). Included in opaque cultural knowledge are "arbitrary referential symbols" (p. 127) – i.e., words. In this theory, ostensive cues such as eye contact and infant-directed speech are seen as playing an important role in early learning of *generalizable* information, with object labels being particularly good examples of generalizable information. And yet these cues are typically not present when learning through overhearing (or, if they are, they are not directed to the child learner). The fact that toddlers can learn object labels through overhearing demonstrates that early learning of generalizable knowledge does not *require* direct ostensive communication. Whether ostensive communication in the form of child-directed speech plays a facilitative role in early word learning is an issue to which we return in the next part of this chapter.

While, in general, child-directed speech may be beneficial for word learning, in some contexts, and for some children, it may be easier to learn from overheard speech than from child-directed speech. Although much work needs to be done to flesh this out, it is possible, for example, that children who are temperamentally shy, and children on the autism spectrum, may benefit from opportunities to overhear speech (see final part of this chapter for directions for future research). One hypothesis then is that some groups, or some individuals, may learn better through overhearing than through direct teaching interactions. Studying who benefits from overhearing the conversations of others would allow us to understand and support these inter-individual and inter-group differences.

Third-party learning of words and phrases may well be a common strategy in early language learning, especially if we look beyond the Western, educated, middle-class context. There are

well-established cultural differences in the amount of speech adults direct to children (Brown, 1998; Crago, Allen, & Hough-Eyamie, 1997; Schieffelin & Ochs, 1986; Shneidman & Goldin-Meadow, 2012). Anthropologists and linguists have shown that young children in some communities experience far fewer one-on-one interactions and far less child-directed speech than children growing up in the Western middle-class context. Nonetheless, they still learn language. While the implication is that these children are probably learning their early words from listening in on others' conversations, we believe it is quite likely that *all* children in *all* cultural contexts learn some of their early language from third-party conversations. Indeed, studies with adults learning a second language show benefits to pronunciation of having overheard that language as a child (Au, Knightly, Jun, & Oh, 2002; Knightly, Jun, Oh, & Au, 2003), suggesting long-term retention of overheard phonemes.

In fact, for some kinds of words, monitoring third-party conversations may be necessary. Yuriko Oshima-Takane has argued quite convincingly that learning the appropriate use of personal pronouns like *me* and *you* may require hearing those words used in third-party conversations (Oshima-Takane, 1988; Oshima-Takane, Goodz, & Deverensky, 1996; Oshima-Takane, Takane, & Shultz, 1999). If one only ever heard the word *you* used in reference to oneself, one might think that it was one's name; early in development, some children do tend to make this mistake, referring to themselves as *you*. But overhearing others also addressed as *you* leads to the more appropriate inference that *you* has shifting reference and is used to refer to whoever is being addressed. So, learning some words – like personal pronouns and maybe other deictic terms that have shifting reference – may *require* attention to third-party conversations.

Despite these benefits of overhearing, almost all of the empirical research on linguistic input examines only speech that is directly addressed to children. Of course, there are practical reasons for this: it is much more difficult to get samples of speech that children overhear, and it is also difficult to know for sure that children are attending to all the speech they overhear. Importantly, though rarely acknowledged, this is also true of speech directed to children. Because children do not always attend to everything said to them, actual input (or, more accurately, uptake; Clark, 2007) probably consists of only some of the speech directly addressed to children and only some of what they overhear.

A final reason for studying word learning through overhearing is that it highlights children's motivation to learn without adults directing their attention. From a very young age, children are very active participants in their own language development. Overhearing studies reflect the real-life contexts in which young children encounter and learn words.

## What we know about word learning through overhearing

The results of experimental studies introducing novel words to toddlers indicate that by the middle of the second year, both German (Gampe, Liebal, & Tomasello, 2012) and U.S. (Floor & Akhtar, 2006) toddlers can learn novel object labels from third-party conversations. Moreover, they learned these novel words equally well through overhearing as when they were directly addressed. At 24 months, English-learning toddlers in the U.S. can learn both nouns and verbs from third-party interactions, although nouns seem somewhat easier for them (Akhtar, Jipson, & Callanan, 2001). By 30 months, they performed equally well with nouns and verbs (Akhtar et al., 2001). At 30 months, they also were able to learn object labels from a third-party interaction when engaged in a distracting activity, and even when the novel words were embedded in directives (e.g., "Can you put the *toma* in here?") rather than ostensive labeling statements (Akhtar, 2005b). They were more likely to shift their attention from a distractor to a third-party interaction when the adults in that third-party interaction used a novel word

(Akhtar, 2005b, Martinez-Sussmann, Akhtar, Diesendruck, & Markson, 2011). Monolingual English-learning toddlers aged 30 months can also learn Spanish object labels from a third-party interaction, provided the label is embedded in an English utterance (Menjivar & Akhtar, unpublished data).

Somewhat surprisingly, at 30 months, children seemed to learn object labels better from a televised third-party interaction than a televised interaction in which one person appeared to directly address them – but only when that televised interaction involved reciprocity between the two people they observed (O'Doherty et al., 2011; Roseberry, Hirsh-Pasek, & Golinkoff, 2013; but also see Krcmar & Cingel, 2017). This unexpected finding points to reciprocity as a critical ingredient in both direct and third-party word-learning contexts. Whether interacting directly with the speaker, or observing a speaker interact with another individual, children appear to learn better from a conversation that includes engagement of both participants. This finding also highlights the ways in which learning through overhearing may be situated within modern communication technology, in particular screen media.

One criticism of the experimental studies of word learning through overhearing concerns the type of speech used in the third-party conversation. While the speech was not directed to the child participants, it nonetheless may have appeared to be designed for them as the experimenter spoke excitedly about the novel objects. Put another way, perhaps it was the acoustic characteristics of the speech that drew children's attention to the third-party interaction and helped them learn from it. A recent series of studies (Shimpi & Akhtar, unpublished data) indicates that these acoustic characteristics may not be necessary if children are already attending to the third-party interaction, but may assist in directing their attention to it when they are engaged with something else. In these studies 18- and 24-month-old toddlers were randomly assigned to overhear conversations within either an adult-directed speech condition (in which the experimenter spoke in a flat, uninflected monotone) or a child-directed speech condition (more excited talk with higher fundamental frequencies). Both age groups learned a novel object label equally well in the two conditions, but a follow-up study indicated that when given a distracter toy to play with, 24-month-olds only learned the label in the child-directed speech condition. Thus, when they were engaged in another activity, the acoustic characteristics of child-directed speech spoken to others acted to attract toddlers' attention to the third-party interaction, enabling them to learn a word from it.

A major impetus for the early experimental studies of learning through overhearing came from observational studies demonstrating both inter- and intra-cultural differences in the extent to which young children monitor third-party interactions. In indigenous-heritage communities in North and Central America, for example, children tend to be expected to monitor and learn from third-party interactions, and in those cultures very young children do seem to be keen observers of others' interactions (Rogoff, Correa-Chavez, & Silva, 2011). These inter-cultural differences are likely due to differences in the frequency of interactional routines in which children are expected to take on the role of observer or bystander. For example, children in Taiwanese families in Taipei were found to engage in overhearing of narrative storytelling at a rate double that of children from European American families across the third year (Miller, Fung, Lin, Chen, & Boldt, 2012).

It is possible that growing up in a context in which one regularly experiences polyadic interactions can lead to the development of strategies of attending to third-party interactions that aid children's learning from overhearing. If this is true, then children who have more experience in polyadic (relative to dyadic) interactions should have an advantage in learning from overheard speech because polyadic interactions afford more opportunities for overhearing. Consistent with this hypothesis, Laura Shneidman and her colleagues demonstrated that at 20 months the

amount of time toddlers in Chicago spent with multiple adults (i.e., in polyadic contexts) predicted their attention to a third-party interaction as well as their ability to learn a novel object label from it (Shneidman, Buresh, Shimpi, Knight-Schwarz, & Woodward, 2009). One might predict, on the basis of this study, that children growing up in cultural contexts with even more polyadic experiences might be even better at learning words through overhearing. Recent findings from naturalistic observational studies, however, paint a different picture.

In these naturalistic studies, researchers compared child-directed speech and overheard speech as predictors of vocabulary size in very young children. They quantified the amount of speech directed to children and the amount children overheard and correlated those measures with measures of language development, including vocabulary size. In the earliest stages of language learning, child-directed speech was a better predictor than overheard speech. In a case study, a child being raised trilingually in the U.S. was recorded continually (all day) for 11 days between the ages of 11 and 24 months (Oller, 2010). A random sample of 39 5-minute recordings was used to assess the words spoken by the child as well as those spoken by her parents and nanny. The language spoken directly to the child was a much stronger predictor of the child's word tokens and word types than (overheard) speech between her parents. It must be noted, however, that in this sample there were more than five times more words directed to the child as overheard, making it unclear to what extent the effects were due to the frequency of the words heard in direct speech. Moreover, the child speech and adult speech were transcribed from the same sessions and therefore were not independent. However, other larger studies with independent measures of parental speech and child have resulted in similar findings.

In a study comparing rural Yucatec Mayan children in Mexico and urban children in the U.S. (Shneidman & Goldin-Meadow, 2012), Mayan 1-year-olds experienced proportionally less direct input than a comparison sample of U.S. 1-year-olds; this proportion grew over time (1 year to 3 years) in the Mayan sample but not the U.S. sample. Mayan children heard and overheard more speech from other children (69% of total input) than the U.S. children (10% of total input) did.[1] More importantly for our purposes, at 24 months, in both groups, it was only direct input from adults (as opposed to direct input from other children and overheard input) that predicted subsequent vocabulary development (a composite measure of vocabulary, averaging receptive and expressive scores). Thus, in this study, it was not the amount of overheard speech that predicted vocabulary, only the amount of child-directed speech.

Shneidman and colleagues conducted a similar analysis on within-culture variation in direct versus overheard speech in a sample of 30 families from the Chicago area who varied in terms of the relative frequency of single-speaker interactions and multi-speaker interactions with and around children. The children received similar amounts of total child-directed speech, when speakers were pooled, but the children with more experience with multi-speaker interactions heard more speech in total (both tokens and types) when direct and overheard utterances were pooled. However, again it was only the quantity of child-directed speech at 2;6 that predicted receptive vocabulary a year later (Shneidman, Arroyo, Levine, & Goldin-Meadow, 2013).

Similarly, Weisleder and Fernald (2013) found a high degree of variation in child-directed speech within a sample of low-income Spanish-speaking U.S. families. These researchers expanded the focus beyond vocabulary size in their research on the role of child-directed and overheard speech to include an analysis of the relations between linguistic input and language-processing efficiency. Processing efficiency was measured using the looking-while-listening task, in which children heard sentences involving common vocabulary terms while looking at two images, one of which was named in the sentence heard, with the proportion of time spent looking at the named object taken as an indicator of speech-processing efficiency. The researchers found a positive correlation between amount of child-directed speech at 19 months and

expressive vocabulary size at 24 months, and replicated a previous finding that child-directed speech predicted later processing efficiency (Hurtado, Marchman, & Fernald, 2008). They also found that processing efficiency mediated the relation between child-directed speech and vocabulary, but overheard speech did not predict later vocabulary size. No evaluation of the relationship between amount of overheard speech and processing efficiency was reported.

These results suggest that direct input may be particularly important for early word learning, but seem to contradict both the experimental studies that show equivalent word learning in direct and observational contexts, and the findings that children growing up in cultural contexts without much child-directed speech do learn words. The experimental studies suggest that it is just as easy for toddlers to learn words from overheard speech as direct speech, whereas the observational studies indicate that speech directed to children, but not overheard speech, predicts subsequent vocabulary size. Future research will need to reconcile these apparently contradictory findings. One potential resolution to this conflict may lie in the acoustic characteristics of naturalistic overheard speech. In the experimental studies, pitch and intonation are generally intentionally similar across conditions (Akhtar et al., 2001) except when they are manipulated to be different (Shimpi & Akhtar, unpublished data). In naturalistic settings, overheard speech is more likely to be less salient (lower and less variable pitch) than child-directed speech, at least in the Western, middle-class context. Because acoustic characteristics are especially important when very young children are distracted (Shimpi & Akhtar, unpublished data), this difference alone may explain the discrepancy between the experimental and observational studies' findings: children are more likely to face multiple distractors in naturalistic than in laboratory settings, and naturalistic overheard speech is less likely to be attention-grabbing than child-directed speech. We explore related potential explanations for these contradictory findings in the concluding part of this chapter.

Early studies of vicarious word learning demonstrated that learning through observation is a fertile context for early word learning; more recent studies have begun to dig deeper to examine aspects unique to the overhearing context. While direct and overhearing contexts share a speaker who performs similar actions, the overhearing context also includes another participant: the active listener, the recipient or addressee of the speaker's attention and talk. As discussed earlier, the observation of contingent, reciprocal interaction between speaker and addressee appears to be a key ingredient in learning through overhearing (O'Doherty et al., 2011).

In all of the experimental studies discussed thus far, reciprocity involved the addressee smiling and nodding in response to the speaker's use of a novel label, taking the object, and then smilingly handing it back. In a recent study, 4-year-olds observed the typical labeling sequence, but with addressees who responded either positively, by nodding and smiling, or negatively, by frowning and shaking their heads (Tolins, Namiranian, Akhtar, & Fox Tree, 2017). When addressee responses were produced after repeated speaker presentations of the label (e.g., "I'm going to show you the *toma*; Do you want to see the *toma*?; I'm going to show you the *toma*" spoken back-to-back), children learned the label equally well regardless of the valence of the addressee's response. However, when the addressee responses were embedded in a sequence such that the speaker repeated the label after receiving addressee feedback (the addressee either nodded or shook her head after each of the three presentations of the novel word *toma*), word learning was boosted when label repetition occurred after negative addressee responses. Our interpretation of these findings is that children made inferences about why the conversational participants they observed were behaving the way they were. They saw speaker repetition of a label following positive listener response as just that – repetition – whereas speaker repetition of a label following negative listener response led to an interpretation of the speaker's actions as reinforcing the label and insisting on its correctness. This finding suggests that children at this

age are not just attending to the speaker in isolation; instead, they attend to the relation between the contributions of the speaker and the addressee in interpreting a third-party interaction, a process unique to the overhearing context.

## Directions for future research

In this part we explore several issues in studying learning through overhearing and suggest directions for future research on this topic. We begin by reflecting on the variety of contexts that might be considered to involve overhearing, and then examine a number of factors that may affect direct learning and learning through overhearing differently. These include age, the type of information being learned, how and when learning is assessed, the sociocultural and socioeconomic context, the situational context, and individual differences in temperament and language learning style. To complicate matters, all of these factors likely interact in interesting ways.

### *What counts as overhearing?*

With increasing evidence that studying learning through overhearing has merit in its own right – beyond simply comparing it to learning from child-directed speech – comes awareness of a number of issues that have not previously been prominent. One issue is the definition of overhearing itself. While so far we have treated overhearing with the broadest definition – as children's listening in on conversations but not participating – it is useful to consider how overhearing can vary across settings. Is being co-located in the same space a requirement for an overheard setting? What about being co-present, but not co-located, such as when children are in the videochat frame of a conversation between their parents and their grandparents? What about being co-present but not co-temporaneous, such as when children view a video recording of parents talking to grandparents? Does it matter if those being overheard are familiar or unfamiliar individuals? Going further, how spontaneous does the conversation need to be? Should it feel like a natural conversation, or could it be a scripted conversation? If all of these seem like they could involve overhearing, should learning from television shows and movies also be considered a type of learning through overhearing (see Chapter 25, this volume)? Some might believe only contexts in which the speaker and addressee are unaware of the child's presence should count as overhearing, while others might include any speech that is not directed to the child as overheard speech.

"Overhearing" itself may be too general a term, glossing over a variety of different social configurations and interactions. Overhearers may be side participants in an interaction involving multiple speakers with shifting speaker and direct addressee roles. They may also be ratified bystanders, who are acknowledged as a member of an interactional scene even if they do not actively participate, or they may be eavesdroppers who are neither acknowledged nor taken into consideration by those with active roles (Schober, 1998). The degree to which talk is designed specifically with non-active participants in mind may influence both the quality of the speech and the degree to which it is comprehensible by third parties (Fox Tree & Mayer, 2008).

Even if we develop some consensus on what overhearing is, in naturalistic settings separating out what was learned from direct speech and what was learned from overheard speech can be tricky. In their everyday lives children are highly likely to hear any given word in both contexts, and in fact the two contexts are complementary, as parents who are asked to define a word from an adult conversation for an overhearing child can attest. Although it is artificial to treat direct learning and overhearing as separate learning contexts, this was necessary in the early stages of research on this topic to show that learning could take place by overhearing alone. We now need to move on to studying how direct learning and overhearing complement each other.

## Age

Whether and how well children learn from overhearing likely depends on their age. The correlational studies reviewed above suggest that direct teaching may be particularly beneficial for word learning earlier in development; however, the importance of the quantity of child-directed speech declines as children develop (Rowe, 2012). Thus, it is possible that the relative roles of direct versus overheard speech may change over time as well. Similarly, younger toddlers (18 months) are more likely to imitate a novel object-directed action when directly shown it than when they observe an adult demonstrate it to another adult (Matheson, Moore, & Akhtar, 2013). However, in some cases, direct teaching leads to restricted exploration in young children (Bonawitz et al., 2011; Shneidman, Gweon, Schulz, & Woodward, 2016). Thus, whether direct teaching is better than learning through overhearing appears to depend on both the age of the learner and the specific goal of learning.

## Moving beyond object labels

We also need to study different types of words. The vast majority of studies of young children's word learning focus on the learning of content words, in particular, novel nouns that are labels for concrete objects. But language learning also involves learning function words, such as articles and prepositions, and non-typical words such as discourse markers (such as *well* and *oh*), fillers (*um* and *uh*), and words that express emotions (such as *ouch*, *wow*, and swear words). While many non-content words are not usually directly taught (for example, discourse markers are not typically taught to second language learners; Fox Tree, 2010), it is nonetheless difficult to assess learning of these words through overhearing because children may have been exposed to them many times by the time they come into the lab. One possibility is to create novel prepositions or discourse markers in the lab and to compare learning from child-directed speech to learning through overhearing. These novel words could be prepositions and discourse markers from languages the child does not have exposure to.

It would also be informative (though admittedly difficult) to follow children longitudinally to see if words they encounter in naturalistic contexts only through overhearing (e.g., swear words) are as likely (or more likely) to be retained (and/or produced) subsequently than equally emotion-laden words heard only in child-directed speech. Our hypothesis is that being somewhat removed from the emotional context might allow the child to devote more processing resources to learning (Rice, Levine, & Pizarro, 2007); thus, we would predict an "advantage" for the overhearing context for learning terms used with great (negative) emotion.

## Moving from measures of quantity to measures of quality of overheard speech

The correlational studies of overheard input all examine the relations between overall amount of overheard speech (whether word tokens or word types) and outcome measures such as vocabulary or word processing speed. This is of course a valuable first step, but we need to now move to examining the content of overheard speech in a much more detailed way. For example, Sperry, Miller, and Sperry (2017) have suggested examining overheard speech that is about the child separately from overheard speech that concerns other people, reasoning that children may be more likely to attend to (and presumably learn from) speech that is about them. They also suggest examining the processes by which children might extract meaning from overheard utterances; e.g., by using distributional analyses of syntactic contexts in which verbs appear. It is quite

likely that some of the speech very young children overhear between adults may be beyond their syntactic and lexical comprehension. It's possible children might learn more from being exposed to more complexity, but it's also possible they might learn less if the language is too complex for them to follow. Much remains to be studied about the linguistic characteristics of overheard speech relative to child-directed speech.

## *Moving beyond comprehension as a measure of learning*

Most of the experimental studies we have reviewed use comprehension as the outcome measure of learning. It would also be instructive to measure the relative frequency with which children *use* words they have heard in direct versus third-party conversations, as has been done with the spatial terms *between* and *middle* (Foster & Hund, 2012; Hund, Bianchi, Winner, & Hesson-McInnis, 2017). We need more studies that examine whether and when (i.e., after exposure to how many models) young children begin to spontaneously use words learned through overhearing versus words learned from speech directed to them, and whether this varies with the parts of speech those words belong to.

## *Retention of words learned through overhearing*

As reviewed above, speech directed to young children by their primary caregivers better predicts vocabulary knowledge than overheard speech in both U.S. (Shneidman & Goldin-Meadow, 2012; Weisleder & Fernald, 2013) and Mayan (Shneidman et al., 2013) toddlers. This could be because words learned through direct speech might be better retained than words learned through overhearing. However, it is still an open question whether retention is better or worse after learning through overhearing. In direct learning settings, 24-month-olds who demonstrate learning after a 5-minute delay in a referent selection task show relatively poor retention of that learning after 24 hours (Horst & Samuelson, 2008). In most of the experimental studies of word learning through overhearing, learning is assessed very soon after exposure to a new word, and it is not clear how long these words are retained.

Retention of words learned through overhearing may vary as a function of cultural context. U.S. and Mayan 18-month-olds were taught one word directly and one word through overhearing (in counterbalanced order) and then tested for comprehension immediately and then one week later (Burke, Woodward, & Shneidman, 2017). Direct teaching led to better long-term retention of words in U.S. toddlers in comparison to overheard words. But for Mayan toddlers, direct teaching led to similar learning as overhearing. For U.S. toddlers, there was no significant retention of the word learned through overhearing a week later, but for Mayan toddlers, there was equally good retention of the word they had learned through overhearing. It is possible that some children (e.g., those with more experience keenly attending to third-party conversations) may retain what they overhear longer than others.

## *Socioeconomic context*

The most widely cited study examining links between socioeconomic status (SES) and vocabulary development is that of Hart and Risley (1995). That study, however, only included speech directed to young children, and only speech directed to them by their parents (actually only one parent: the mother), in the calculation of the so-called 30 million "word gap" between children from low SES backgrounds compared to their middle-class counterparts. That study was also restricted to a sample of 42 families in Kansas. A recent study with a more geographically and

ethnically diverse sample indicates significant differences across communities within the U.S. in the amount of child-directed and overheard speech as well as differences in who (children or adults) toddlers are overhearing and being addressed by (Sperry, Sperry, & Miller, 2018). More specifically, these researchers did not replicate Hart and Risley's main finding when they examined speech directed to children; that is, there was no clear relationship between social class and amount of speech directed to children. Moreover, when overheard speech was included in the total number of words heard, the lower-SES children heard *more* words than the middle-class children. Finally, there was a great deal of variability within each socioeconomic stratum. Of course, the next step is to see whether, and how much of, the ambient speech is attended to and learned from, and how this changes with development.

## *Situational factors*

With respect to the situational context, learning may depend on who the children are observing; i.e., children's familiarity with the people modeling new words and actions. In one study, familiarity did not affect learning a novel action through overhearing, but impacted direct learning such that when the "teacher" was completely unfamiliar, children were highly unlikely to imitate her. Indeed, they were far more likely to imitate actions they observed unfamiliar adults perform than to imitate actions taught to them directly by an unfamiliar adult (Shimpi, Akhtar, & Moore, 2013). But learning of words may be different. Because children seem to recognize the conventional nature of words from a very young age (Clark, 2014; Graham, Stock, & Henderson, 2006), familiarity of the speaker may not affect children's learning of words. While the identity of the addressee in the third-party interactions (e.g., sibling vs. unfamiliar child) does not seem to impact learning of a novel action (Shimpi et al., 2013), a direct test of children's word learning through overhearing familiar and unfamiliar adults remains to be done.

Other situational factors that will also need to be studied systematically include: the setting (lab, home, school, indoors, outdoors) and its familiarity; whether children are overhearing on their own or in a group; the type of interaction being observed (video vs. live; actors vs. cartoons); and the relevance and salience of the information being overheard.

## *Individual differences*

Individual differences related to temperament and language learning style (e.g., referential versus expressive; analytic versus holistic; Bates, Bretherton, & Snyder, 1988) may predict children's preference for and/or ability to learn through overhearing. The temperamental dimension of sociability in particular may affect learning preferences; extraversion and positive affect predict word production and other language measures (Dixon & Smith, 2000; Perez-Pereira, Fernandez, Resches, & Gomez, 2016; Slomkowski, Nelson, Dunn, & Plomin, 1992). Hilton and Westermann (2016) found that shyer 24-month-olds were less likely to learn and retain a novel word taught directly to them by an experimenter. Although we know of no studies examining relations between temperament and learning through overhearing, it is worth investigating whether introverted toddlers learn more or better (longer retention) from overhearing than those who are more gregarious. As indicated previously, when toddlers learned novel means-ends actions from unfamiliar people, they learned better through overhearing (Shimpi et al., 2013). Our hypothesis is that children who are temperamentally shy or withdrawn might also be better at learning new words from third-party interactions.

### *Neurodiversity*

Similarly, children who experience difficulties in social interactions, or who find them particularly stressful, might benefit from learning through overhearing. Luyster and Arunachalam (2018) suggest that one-on-one interactions may be overwhelming for children on the autism spectrum. Their hypothesis was that autistic children might perform better when learning words through overhearing than through direct teaching interactions as the overhearing context does not involve social pressure. Thirteen 4- and 5-year-old autistic children were taught one word directly and one word through overhearing (in counterbalanced order) and then tested for comprehension. These children learned equally well (and at above chance levels) in the addressed and overhearing conditions. With such a small sample size there may not have been enough power to detect a difference between the conditions, but the findings offer proof of concept that autistic preschoolers can learn new words through overhearing.

It has also been suggested that some instances of echolalia – immediate or delayed repetition of phrases often seen in autistic individuals – may be learned through overhearing (Ghofrani, Luyster, & Arunachalam, 2017). This is important because echolalia can serve as a stepping-stone to the productive use of grammar (Blanc, 2012; Gernsbacher, Morson, & Grace, 2016). We do not know of any studies that have directly compared the frequency of echolalic phrases derived from direct versus overheard speech, but our hunch is that more may be learned from overheard speech than from direct speech (especially if we consider learning from videos to constitute learning through overhearing; Suskind, 2014).

## Conclusions

It seems paradoxical that multiple correlational studies (from multiple labs) have found no relation between measures of overheard speech and vocabulary, yet multiple experimental studies (from multiple labs) indicate that toddlers can learn new words through overheard speech in the lab. One possibility is that the lab situations are too artificial and not like real-life overhearing situations. Another possibility, however, is that this seeming paradox is due to how little we currently understand about the factors (explored in the preceding part) that play a role in young children's attention to and learning from third-party conversations. Young children likely hear and attend to *most* speech directed to them as this speech is often designed to capture their attention (Shneidman & Woodward, 2016) or spoken while children are already attending – that is, during periods of joint attention. However, they probably only attend to *some* of the speech that is directed to others. In addition, some overheard speech is likely so far beyond children's comprehension that they are unable to gain enough of a foothold to learn from it. The correlational studies examining links between overheard speech and vocabulary generally include all ambient language as overheard speech; thus, they collapse overheard speech that children attend to and overheard speech that children may not even have heard, much less attended to. We hypothesize, for example, that a young child may be more enticed to attend to a whispered conversation between their parents (especially if they mention the child's name) than to conversations on topics that are less interesting or comprehensible to them. Future correlational studies will need to find ways to differentiate between ambient speech that was attended to (overheard) and ambient speech that was ignored. This is no easy task, but it will be necessary if we are to fairly compare child-directed speech and overheard speech as predictors of language development.

We anticipate that, one day, when we ask undergraduate students how they think young children learn new words, they will say something like, "Children hear people around them use

the word, and infer what the word means based on their observations. And sometimes they are taught words by others". The distance between where we are now and where we are headed will be marked by investigations into the conditions under which learning through overhearing is enhanced, including what is being learned, when it is being learned, where it is being learned, by whom it is being learned, with whom it is being learned, and how learning is assessed. For a long time now the developmental literature has implicitly or explicitly associated learning with teaching, and language learning in particular with child-directed speech. In this chapter we have tried to shine a spotlight on children's motivation and ability to learn when not being directly taught.

## Note

1 It is important to note that Shneidman and Goldin-Meadow also found that Mayan children received less input when videotaped; thus, caution is needed in interpreting the overall frequency of talk to and around these children.

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# 23

# LEARNING LANGUAGE IN THE CONTEXT OF PLAY

*Catherine S. Tamis-LeMonda and Jacob Schatz*

Children live in the moment. They do not keep tabs on time, worry about being late, check the status of to-do-lists, or attempt to fit many pressing obligations into a day. Instead, they play. They move their bodies for the sheer fun of moving. They bang, rotate, combine, and pretend with objects, for the sheer fun of discovery. They coo, babble, and soon use words and sentences for the sheer fun of connecting with others. And children find creative ways to turn the activities of everyday life – eating snacks, taking baths, and getting dressed – into playful escapades – finger painting with applesauce, splashing water onto the floor, and playing peek-a-boo from under a coat. In the famous words of Maria Montessori: Play is the work of children.

What does any of this have to do with language? We would argue everything. Play dominates children's days. It is what they *do*. And consequently, play is a primary context for learning language. Play provides an unparalleled opportunity for children to hear words for the objects and activities around them and to build an understanding of how the world works. During everyday play, children generate perceptual and social feedback about the people and things, spaces and places of their environments. Most of that feedback is exquisitely time-locked to what children are doing, and much is in the form of language. When infants explore objects, they often hear words that refer to the objects of their actions ("You're feeding daddy cheerios!"). When they roam from place to place, they often hear words about actions and locations ("Come over here!" "Walk slowly or you might fall!"). When children talk, they elicit language that interprets and expands on their utterances ("Yes, we saw a monkey at the zoo"). And when they pause to interact with available toys – for example, by fitting shapes in shape sorters and stacking blocks – they create opportunities to hear language that is unique to those objects – such as words for shapes, numbers, locations, and spatial relations.

Perhaps, most centrally, play is all-engrossing. Children are deeply invested in what they are doing, and thus poised to benefit from the language that is directed to them from the first days of life. Indeed, infants learn language best when words refer to the objects and events receiving their attention and are couched in interactive, meaningful contexts (Konishi, Kanero, Freeman, Golinkoff, & Hirsh-Pasek, 2014). Parents who attune to their infants' everyday play behaviors with lexically rich, contingent language increase the odds that their infants will map the words they hear to environmental referents, thereby supporting language learning in the early years (Tamis-LeMonda, Kuchirko, & Song, 2014; Tamis-LeMonda & Bornstein, 2016).

In this chapter on early language development, we advance the idea that much of learning occurs in the context of everyday play. We first review the features of parent language input that support children's language learning, particularly in infancy, including amount of language, diversity of language, embodied cues to language inputs, and contingent responsiveness. We show that many of these features characterize language during child-parent play interactions. Next, we examine how different forms of play change in prominence from infancy through early childhood, elicit unique language inputs from adults, and thus arm children with words and concepts that are springboards to school readiness. We focus on "object play" in all its richness and scope, ranging from the early exploratory actions of infants to the pretend stories of preschoolers. As we describe in the concluding part, we do not view play as confined to manufactured toys or pretending. Rather, children play with lots of things, in lots of places, during everyday activities, and with multiple partners. These interactions provide children with valuable opportunities to exercise language, social, cognitive, and emotional skills. We end by introducing ways to support parents' language interactions with children by raising awareness of the role of play in learning and development.

## Features of language input that support learning

Children can only learn the words to which they are exposed. Adult language input is thus foundational to early language development. Parents – the primary purveyors of young children's language experiences – support language learning by providing a lot of language and lexically rich language in contingently responsive ways. The amount and diversity of parent language input (Bornstein, Haynes, & Painter, 1998; Hirsh-Pasek, Adamson, et al., 2015; Rowe, 2012; Tamis-LeMonda, Song, Leavell, Kahana-Kalman, & Yoshikawa, 2012), vocal and physical embellishments that accompany child-directed language input (Brand, Baldwin, & Ashburn, 2002; Golinkoff, Can, Soderstrom, & Hirsh-Pasek, 2015), and temporal alignment of language with infants' exploratory and communicative behaviors facilitate infants' learning of the phonological, lexical, grammatical, and pragmatic components of language (Bornstein, Putnick, Cote, Haynes, & Suwalsky, 2015; Brand, Hollenbeck, & Kominsky, 2013; Tamis-LeMonda, Cristofaro, Rodriguez, & Bornstein, 2006). Notably, the features of input that support language learning are prominent in language exchanges during play.

### *Rich language: amount and diversity*

Children benefit from hearing a lot of language early in development. Frequent exposure to language allows infants to extract phonological and semantic regularities from the input. Indeed, language quantity, or "tokens" (the number of words directed to infants), facilitates growth in children's vocabulary (Bornstein et al., 1998; Hoff & Naigles, 2002; Huttenlocher, Haight, Bryk, Seltzer, & Lyons, 1991). Relatedly, the frequent repetition of words, phrases, or entire sentences reinforces new vocabulary and highlights consistency in grammatical structures. Mothers' repetition of words at 7 months predicted infants' vocabulary skills at 2 years of age (Newman, Rowe, & Bernstein Ratner, 2016). Repetition in language is especially important during infancy, in part because repetition increases the duration of time an infant spends attending to the novel object being labeled (Hollich et al., 2000). Infants also prefer and attend to speech that contains repeated utterances over speech with fewer repetitions (McRoberts, McDonough, & Lakusta, 2009). For the most part, parents intuit the importance of repetition: They direct language to infants that contains many repetitions and therefore reinforces word meaning and provides

multiple opportunities for infants to process the utterance (McRoberts et al., 2009). Over age, as children gain skills in language, they rely less on repetition. Fathers of 2-year-old children with larger vocabularies repeated words *less* often than did fathers of toddlers with relatively smaller vocabularies (Schwab, Rowe, Cabrera, & Lew-Williams, 2018).

Unsurprisingly, language quantity alone, without sufficient diversity in the input, falls short of fostering aspects of language development such as vocabulary growth. As children develop, language acquisition increasingly relies on lexical diversity (Rowe, 2012), or the number of different word *types* in the input. The lexical diversity of parents' speech to infants relates to infants' vocabulary size and growth (Bornstein et al., 1998) and communicative diversity, as captured in infants' use of simple words and phrases to communicate a variety of ideas (Song, Spier, & Tamis-LeMonda, 2014). Notably, lexical diversity in mother and father language input relates to the lexical diversity of children's expressive language (Tamis-LeMonda, Baumwell, & Cristofaro, 2012), and its importance cuts across families from different socio-economic strata and ethnic/racial backgrounds (Pancsofar, Vernon-Feagans, & The Family Life Project Investigators, 2010). In turn, infants who have large vocabularies (relative to same-age-matched peers) display efficiency in language processing, as indicated by quick reaction times to identifying the correct picture in response to naming of an object (Weisleder & Fernald, 2013).

Returning to the premise that play is a primary context for language learning, parent language repetition and diversity are likely to be high during play with children. Play interactions are often marked by routinized and recurring actions, such as nesting shape after shape while labeling them, and naturally lend themselves to rich lexical input. Indeed, parents talk and repeat actions more when enacting a mealtime activity with their 18-month-olds during play than when actually feeding their infants (Lillard & Witherington, 2004). Moreover, play offers opportunities to introduce new vocabulary terms, which is why language inputs during shared object interactions are marked by high lexical diversity (Tamis-LeMonda, Kuchirko, & Tafuro, 2013). And, as will be discussed later, different forms of play afford unique opportunities for children to hear new words and syntactic structures, further supporting language acquisition.

## *Infant-directed speech and action*

Adult speech to infants – often referred to as infant-directed speech – has unique characteristics that support language acquisition. These include higher pitch, enunciated consonants, elongated vowels, and exaggerated prosody. Infant-directed speech has been observed in mothers and fathers (Fernald et al., 1989), bilingual families (De Houwer & Bornstein, 2016), deaf signing parents (Erting, Thumann-Prezioso, & Benedict, 2000; Masataka, 1992), and parents from different cultural communities (Snow et al., 1976; but see Ochs, 1982; Ochs & Schieffelin, 1984; Schieffelin & Ochs, 1979; Pye, 1986).

The special features of infant-directed speech make it especially salient to infants. Infants attend more to infant-directed speech than to adult-directed speech (Fernald, 2000; Schachner & Hannon, 2011), which by definition means they are likely to hear and process the words directed to them. Moreover, infant-directed speech aids efficiency of speech processing (Weisleder & Fernald, 2013): When parents elongate vowels and enunciate consonants, they make it easier for infants to identify segments and encode words (Golinkoff et al., 2015). Additionally, novel labels are often the loudest word in a sentence, which helps infants parse unfamiliar vocabulary from the speech stream (Messer, 1981).

Like infant-directed speech, infant-directed action presents infants with exaggerated and repeated movements that elicit attention and aid speech processing (Brand et al., 2002; Brand, Shallcross, Sabatos, & Massie, 2007; Koterba & Iverson, 2009) and word mapping (Matatyaho &

Gogate, 2008). While demonstrating how a novel object works to their infants, mothers use amplified, simpler, and more repetitive motions than when demonstrating to another adult. Parents also pair infant-directed actions with eye contact and gaze, checking on infants at crucial communicative moments to signal to infants information that is worthy of attention (Brand et al., 2013). During play, parents often look to their children to establish shared intentions, which heightens children's engagement in the activity (Lillard et al., 2007).

Parents' gestures likewise support infant language learning by drawing attention to named objects and events and indicating that actions and words create a meaningful unit (Rader and Zukow-Goldring, 2010). Gestures sometimes provide additional semantic information on their own, thereby complementing and extending messages in language (Novack & Goldin-Meadow, 2015). Consequently, gestures support vocabulary growth by helping infants resolve referential ambiguity (Gogate, Bahrick, & Watson, 2000; Masur, 1997): Maternal gestures in infancy predict vocabulary size at 4.5 years of age (Rowe & Goldin-Meadow, 2009).

There is some evidence that certain features of infant-directed speech peak in certain play contexts (Lillard et al., 2007). Parents use a higher pitch range in their speech to 11- and 15-month-olds during pretend play than during instruction outside of play, and pitch range is larger during play with 11-month-old infants than with 15-month-olds (Reissland & Snow, 1996). Parents also use more sound effects during play (DeLoache & Platezer, 1985; Lillard & Witherington, 2004, Lillard et al., 2007), exaggerate their movements during pretend play, and frequently gesture during spatial play such as block building, behaviors found to facilitate infants' word learning.

## *Responsive language: joint engagement and temporal contingency*

Parent joint engagement, contingent responsiveness, and turn-taking likewise facilitate infant language learning. Joint engagement between adults and children is an important communicative device that cues infants to the targets of talk. In the first year of life, parents often take the lead in establishing joint attention by alternating eye contact with their infants with attention toward a shared object (Brand et al., 2013). However, with age, children increasingly initiate joint attention. Children ages 30 and 42 months reliably engage their parents in joint interaction around concrete objects, and increasingly engage parents around representational symbols during play (Adamson, Bakeman, Deckner, & Nelson, 2014). The prevalence of this symbol-infused joint engagement predicts infants' expressive language growth from 24 months to 36 months (Hirsh-Pasek, Adamson, et al., 2015).

During bouts of joint attention, parents' language to infants is likely to be temporally connected to what infants are doing. Contingent responsiveness – adult verbal input that is temporally and conceptually aligned with infants' vocalizations and utterances – provides an important communication foundation for learning language (Hirsh-Pasek, Adamson, et al., 2015; Tamis-LeMonda et al., 2014). Language input that occurs within a relatively brief temporal "window" of infant behavior supports infants' language learning, and predicts later language outcomes (Bornstein, Tamis-LeMonda, & Haynes, 1999; Landry, Smith, Swank, & Guttentag, 2008; Tamis-LeMonda, Bornstein, Baumwell, & Damast, 1996; Tamis-LeMonda, Bornstein, Kahana-Kalman, Baumwell, & Cyphers, 1998; Tamis-LeMonda et al., 2006). Moreover, contingent responsiveness to 9-month-olds relates to infants' persistence during object exploration and cognitive outcomes 8 months later (Banerjee & Tamis-LeMonda, 2007; Bornstein & Tamis-LeMonda, 1997). Contingent responsiveness results in linguistically complex infant babbles as infants shift toward mimicking the sounds of their responsive conversational partners (Goldstein, King, & West, 2003; Goldstein & Schwade, 2008).

Both joint attention and contingent responsiveness foster skills in turn-taking, the quintessential marker of everyday conversations. Parents model turn-taking behavior when they respond contingently to their infants (Tamis-LeMonda et al., 2013), and infants begin to adopt turn-taking behaviors as early as 5 months (Bornstein et al., 2015). Over the course of the second year of life, infants improve in their turn-taking skills, responding to the gestures and language overtures of their mothers with gestural and vocal communications within a 3-second time window (Kuchirko, Tafuro, & Tamis LeMonda, 2017). Conversational turns make language development a "team effort", and engage areas of the brain that are involved in speech production; the reciprocity of language interactions predicts language development after controlling for amount of language input and family socio-economic status (Romeo et al., 2018).

To what extent do joint attention and contingency characterize infant-adult play? By definition, infant-caregiver interactions during play are rooted in joint engagement and attention to actions and objects, and high levels of contingent responding. During play, adults and children jointly attend to shared objects, events, and topics (Bornstein, Tamis-LeMonda, Hahn, & Haynes, 2008) – taking turns, passing objects back, and co-constructing pretend stories and physical structures in a conversational manner (Brand et al., 2007). Notably, mothers' responsiveness to their 13-month-olds' vocalizations during play, but not during mealtime, predicted children's vocabulary at 20 months (Bornstein et al., 1999). Play is social in much the same way that language is social, making play an ideal setting for infants' participation in language exchanges that promote development.

### *Summary*

Language characterized by repetition, lexical diversity, exaggerated prosody and action, and joint engagement and responsiveness facilitates infant language learning by engaging infant attention, marking boundaries between words, and reducing referential ambiguity. Notably, these characteristics abound in playful interactions as well. Play involves repeated, exaggerated behaviors, accompanied by rich language inputs, during activities that are salient and meaningful to infants. Play unfolds in the context of high joint engagement, where the words infants hear are likely to be about the things they are doing. And, as we describe next, the materials and topics involved in play provide infants with opportunities to hear unique language functions and forms.

## Different types of play elicit unique language input

Children's play undergoes dramatic change across the first years of life, just as does language. In fact, remarkable parallels are seen in the development of play and language. Play progresses from single, concrete actions on objects to extended bouts of symbolic play that contain elaborate storylines (Lillard, 2015; McCune, 1995; Tamis-LeMonda & Bornstein, 1991). Across the same time in development, language progresses from single word utterances about the "here and now" to simple sentences to increasingly complex grammatical forms and elaborated narratives (McCune-Nicolich, 1981; Hoff, 2013). These developments are met with new language input from parents and other caregivers that incites further learning. Speech to infants contains grammatically simple phrases (often utterances that contain a single word) that refer to present objects. But as children develop new skills in language and other domains, parents' sentences become longer and incorporate novel verbs and prepositional phrases, reference to mental states and emotions, and talk about the past and future.

Here, we describe developments in children's object play, and show that different forms of play produce opportunities for children to learn unique forms of language. We discuss the concrete, referential language parents provide in response to infants' object exploration; the functional and spatial language parents provide as toddlers play with blocks, puzzles, and number games; and the mental state language that accompanies the emergence of symbolic play in toddlers and later role play in young children. This coverage is meant to be illustrative rather than exhaustive, with focus primarily on children's play with toys and objects to the exclusion of other likewise important types of play (e.g., locomotor play such as games of chase).

## *Exploring objects*

Infants and toddlers spend a lot of time exploring objects. Object exploration generates perceptual feedback about the properties and functions of objects, and provides adults with opportunities to share attention with their infants and talk about what their infants are doing.

### *Features of infant exploration*

Object exploration teaches infants about the properties of objects and what can be done with them. Infants look at, touch, rotate, finger, bang, drop, and mouth objects – exploratory actions that result in valuable visual, tactile, and auditory information about object features. Something as simple as manually rotating an object promotes infants' understanding that objects are three-dimensional and have backsides (Soska, Adolph, & Johnson, 2010). Infants who are able to sit independently without the support of hands, and therefore have hands free to explore the objects around them, display more advanced mental rotational skills than do infants who are not yet sitting independently (Soska et al., 2010). Additionally, object exploration helps infants differentiate between more and less important perceptual and functional characteristics of the objects that populate their world. For example, between 7 and 14 months infants strike objects against one another in an increasingly selective manner, using feedback from different types of surfaces (hard, soft, etc.) and their developing motor skills as a basis for tool use (Kahrs & Lockman, 2014).

As infants engage with objects, they often seek to share those objects with others. They show objects by holding them in the air, offer objects by reaching toward others, and indicate objects through points and other gestures, all in an attempt to get caregivers to attend to what they are doing (Rowe, Özçalışkan, & Goldin-Meadow, 2008; Tomasello, Carpenter, & Liszkowski, 2007). These "social bids" change in form, complexity, and agency as infants progress in their motor, cognitive, language, and social skills (Karasik, Tamis-LeMonda, & Adolph, 2014).

Infants' transition to walking illustrates how exploration and bids with objects change as infants develop new skills in upright locomotion. Home observations of 13-month-old walkers and crawlers revealed intriguing differences in how the two groups of infants explored and shared objects with their mothers. Crawlers explored objects that were within arm's reach, whereas walkers often crossed the room to access distant objects. Moreover, walkers – who were able to locomote upright with their hands free – carried objects to their mothers for sharing, whereas crawlers shared objects from stationary positions (Karasik, Tamis-LeMonda, & Adolph, 2011, 2014). Similarly, when infant language and locomotor development were tracked between the infant ages of 10 to 13.5 months, infants increasingly initiated joint engagement, by pointing and bringing objects to their parents between 2 and 4 weeks after they began to walk; they also grew in their responses to parents' bids for joint object engagement (Walle, 2016).

### *Language in response to infant exploration*

Infants' exploration of objects provides ripe opportunities to learn language. Indeed, much of the language directed to infants is about the objects of their attention (Bornstein et al., 2008). Mothers (and fathers) frequently name objects, talk about object features and what can be done with them, and ask questions about objects and related actions (e.g., "That's a bright red firetruck!", "You can push it along the floor"). These informative language forms, referred to as didactic or *referential language*, are more likely to occur when infants are visually and manually exploring objects than when they are unfocused or off task (Tamis-LeMonda et al., 2013). Conversely, when infants are off task, mothers use *regulatory language* to direct infant attention or actions (e.g., "Look", "Put it there"), in attempts to focus an unfocused child.

Notably, mothers' referential language to 2-year-olds during exploratory play predicts vocabulary size, whereas regulatory language does not (Tamis-LeMonda et al., 2012), largely because characteristics of referential language make it conducive to learning words. First, referential language is timely, with mothers responding within 2–3 seconds of a touch onset (Tamis-LeMonda et al., 2013). When parents label and describe the objects of infants' attention, they introduce meaningful vocabulary within a time window that helps infants connect words to the world (Baldwin & Markman, 1989). Second, referential language is embodied. Parents often accompany referential language with gestures and physical cues that present infants with information across multiple modalities: speech and action (Masur, 1997). Mothers more often pair gestures and exaggerated actions with referential language than with regulatory language (Gogate et al., 2000; Tamis-LeMonda et al., 2013).

Notably, the changes to infant exploration and social bids that accompany the onset of walking (described above) result in different types of verbal responses by mothers. Crawlers' social bids with objects were more likely than those of walkers to be ignored. Of greater interest was the finding that mothers of walkers were more likely to respond to their infants' social bids with action directives that contained verbs (e.g., "Do you want to throw the ball and play catch?"), whereas mothers of crawlers were more likely to merely label the object ("That's a ball") (Karasik et al., 2014). These differences might explain why infants' walking experience relates to their receptive and productive vocabularies (Walle, 2016; Walle & Campos, 2014).

In sum, infants' exploration of objects is often met with rich language input from responsive, jointly engaged adults. The language directed to infants at play is likely to be lexically diverse, rather than pronoun-laden (e.g. "Go get your truck!" instead of "Go get it!"), thus fostering growth in vocabulary. As infants grow in their initiation of joint attention – for example, by actively bringing objects over to their mother – they are exposed to new language forms.

## *Constructive play*

Between 1 and 3 years of age, children progress from visual-manual exploration to using objects and toys in the ways they were designed to be used – for example, discovering that Duplo blocks interlock and that specific blocks fit into specific holes of a shape sorter. Constructive play – which spans activities like building with blocks, nesting shapes in sorters, fitting puzzles, and the like – presents opportunities for children to learn words about spatial relations, shapes, and numbers.

### *Features of constructive play*

Constructive play has received much attention because of its association with later academic outcomes. During constructive play, children must discover relations among objects or parts of objects, accurately orient those objects so that they spatially align, and then effectively implement

the actions (too much of twist of a square block makes it impossible to insert in the correct hole). Spatial knowledge is an important precursor for math achievement (Pruden, Levine, & Huttenlocher, 2011; Verdine, Golinkoff, Hirsh-Pasek, & Newcombe, 2014), and play with spatial toys helps children practice those skills. Toys that require mental and physical manipulations and transformations help children hone their visuospatial, number, and math skills, and relate concurrently (Verdine, Golinkoff, Hirsh-Pasek, Newcombe, et al., 2014) and predictively to math achievement (Geary, 2011; Jordan, Kaplan, Locuniak, & Ramineni, 2007). For example, the frequency of children's puzzle play between 2 and 4 years of age predicted spatial manipulation skills at 4.5 years (Levine, Ratliff, Huttenlocher, & Cannon, 2012), and preschoolers' play with number board games fostered numeracy skills (Ramani & Siegler, 2008; Siegler & Ramani, 2009). Opportunities for constructive play in the early years may be crucial for later development: Vast individual differences in spatial and math skills exist by kindergarten (Case, Griffin, & Kelly, 1999; Newcombe & Frick, 2010; Verdine, Golinkoff, Hirsh-Pasek, Newcombe, et al., 2014) and are stable over time.

### *Language in the context of constructive play*

Beyond opportunities to discover and practice manual and mental rotations of objects, constructive play exposes children to spatial and number language. The spatial language directed to children during block and puzzle play takes many forms, ranging from prepositional phrases to geometric terms to linguistic comparisons of magnitudes and sizes (e.g., bigger and taller than; Ferrara, Hirsh-Pasek, Newcombe, Golinkoff, & Lam, 2011; Levine et al., 2012; Lombardi, Casey, Thomson, Nguyen, & Dearing, 2017; Zosh et al., 2015). Mothers of preschoolers used more spatial terms during block play than during other daily activities, referring to spatial locations, dimensions, shapes, and orientations (Ferrara et al., 2011) – including prepositions such as *on*, *above*, and *under*. In fact, by simply playing with blocks, parents introduce spatial concepts to children, and understanding of spatial concepts supports math literacy, academic achievement, and language acquisition more broadly (Christakis, Zimmerman, & Garrison, 2007).

Board games that require spinners, dice, and numbered spaces likewise prompt specific language inputs – namely number terms involved in counting and number recognition (Ramani & Siegler, 2008; Siegler & Ramani, 2009). Number talk is particularly important for children's cardinal number knowledge – the understanding that a number refers to the full set of items – a springboard for mathematics (Ramani, Rowe, Eason, & Leech, 2015). Mothers varied substantially in their number talk to their 14- to 30-month-olds, and that variation predicted children's cardinal number knowledge at 46 months after controlling for mothers' socio-economic status and general verbosity (Levine, Suriyakham, Rowe, Huttenlocher, & Gunderson, 2010).

Spatial language during play with puzzles, blocks, and board games does more than grow children's vocabularies. It equips them with new ways to observe and reason about the spatial characteristics of the world (Gentner & Loewenstein, 2002). Parents' spatial talk relates to children's spatial talk, and children's spatial talk in turn predicts spatial and math abilities (Pruden et al., 2011). These findings illustrate developmental cascades over time and across domains: The cognitive and bio-mechanical skills children acquire to engage in constructive play lead to new play forms, and these new play forms generate new language inputs. Over time, children's spatial and number skills grow in complexity, and pave the way for later mathematical cognition.

## *Symbolic play*

Symbolic play ushers in a world of imagination, in which toddlers enact "as if" scenarios, washing and cleaning up baby dolls, pouring tea and drinking from empty cups, and lying down to

sleep as if it were bedtime. The early symbolic bouts of toddlers grow in complexity and elaboration with age – eventually developing into the sociodramatic play of preschoolers, in which peers take on complementary roles in shared scripts (e.g., mommy and baby; patient and doctor; Jenkins & Astington, 2000).

## *Features of symbolic play*

Symbolic play and language develop hand in hand. Infants display their first fleeting bouts of symbolic play around the start of the second year, about the time they produce their first words. These first symbolic play bouts involve a single pretend action (e.g., sipping from a cup), extend to combinations of actions midway in the first year, and develop into simple scripts toward the end of the second year (e.g., preparing tea, pouring into a cup, and then drinking). Over the course of the second and third years of life, children incorporate increasingly elaborate scenarios into their symbolic play, and eventually display richly creative fantasy narratives (Fiese, 1990; McCune, 1995). As toddlers extend the length and complexity of their pretend scenarios, they also begin to substitute objects for other objects, for example, using a long block as though it were a spoon or wearing a box like a hat (Tamis-LeMonda & Bornstein, 1993; Tamis-LeMonda & Bornstein, 1996).

These seemingly straightforward play enactments require children to organize actions to reflect their knowledge about the world (first people pour tea, then they drink it, but sometimes they realize it is very hot so they must blow on the cup); suppress reality in favor of the pretend world (there is no liquid in the cup, and of course, nothing is hot); and communicate their play intentions to play partners. The representational and communicative demands of symbolic play provide practice with critical cognitive skills, relating to growth in vocabulary and grammar (McCune, 1995; Tamis-LeMonda & Bornstein, 1991, 1996). Further, object substitutions and sequences of pretend actions at 3 and 4 years of age relate to children's narrative and semantic organizational skills at 7 and 8 years of age (Stagnitti & Lewis, 2015). Pretend play broadly relates to children's executive function skills, perhaps because cognitive flexibility and inhibitory control support pretending, which in turn exercises children's executive functioning (Carlson, White, & Davis-Unger, 2014), and likewise supports children's developing social cognitive skills (Harris, de Rosnay, & Pons, 2005; Jenkins & Astington, 2000; Lillard & Kavanaugh, 2014).

## *Language in the context of symbolic play*

Symbolic play prompts and entails unique forms of language that extend beyond those observed during exploratory and constructive play. As a start, language input during pretend play is richer in lexical diversity than is the language used during the same activity but in a real-life context. Specifically, mothers' language to their 18-month-olds during pretend play around eating contained more concrete and action references (cup, plate, eating) than their language while eating real food (Lillard & Witherington, 2004; Lillard et al., 2007). Further, at the level of sentence structure, language during symbolic play contains meta-communicative sentence frames to establish socially shared goals (e.g., "Let's pretend we are going to shop for food") (Pellegrini & Galda, 1990). Perhaps most centrally, symbolic play offers children opportunities to use and hear vocabulary about the internal states, emotions, desires, and beliefs of self and others (Adamson et al., 2014), as, for example, when a parent says, "I think that Teddy is hungry and tired!", and the child must process the pretend stipulation and identify a solution that will change Teddy's state.

Parents' use of mental state talk, which is infused in symbolic play interactions, facilitates children's developing theory of mind – the understanding that people have unique opinions, beliefs,

points of view, and emotional experiences (Bloom, 2001; Nielsen & Dissanayake, 2000; Osório, Meins, Martins, Martins, & Soares, 2012). Indeed, associations exist among children's pretend play, mental state terms, and performance on theory of mind tasks (Melzer & Palermo, 2016; Nielsen & Dissanayake, 2000). Mothers' use of mental state terms while describing pictures to children predicted children's performance on theory of mind tasks, whereas children's earlier theory of mind performance did not predict mothers' mental state language at a later time point (Ruffman, Slade, & Crowe, 2002), suggesting a causal connection from parent to child. Observations of interactions between deaf children and parents further the claim that conversations enriched with mental state language foster children's theory of mind (Peterson & Siegal, 2000). Deaf children whose parents were not fluent in sign language were severely delayed in theory of mind, whereas children whose parents were fluent in sign language displayed theory of mind skills akin to typically developing hearing children, likely because their parents' fluency in sign language allowed for shared conversations about internal states, beliefs, and emotions.

Finally, symbolic play is an ideal context for children to use and be exposed to decontextualized talk (Adamson et al., 2014) and elaborate narratives that extend beyond the here and now (Uccelli, Hemphill, Pan, & Snow, 2006). By using fantasy-oriented toys such as puppets, parents engage children in fantasy narratives, exercising their children's ability to flexibly shift between different tenses of speech and the mental states of various characters. This flexibility fosters children's later narrative abilities, whereas traditional measures of children's language such as vocabulary and morphosyntactic skill do not (Uccelli et al., 2006).

### *Summary*

As children engage in different forms of play, they encounter words and phrases unique to the objects and actions of their attention. Exploratory play is met with language rich in lexical diversity and physical and prosodic cues to word meaning, precisely at an age when vocabularies and communicative skills are emerging and expanding. Constructive play with blocks, puzzles, shape sorters, and board games introduces children to spatial and math language – such as shape names, numbers, and relational prepositions – that hones skills required for later math and academic achievement. Pretend play moves from the concrete to the imagined world, and ushers in a host of metalinguistic terms and references to mental states and emotions, all of which contribute to children's social-cognition, executive functioning, and metacognitive skills.

## Supporting adults as play partners

Play presents an unparalleled opportunity for children to learn language. However, this claim rests on the assumption that a knowledgeable adult engages the child in play and is a source of high-quality language input. Clearly, reality falls short of the "play ideal". Parents vary substantially in how contingently responsive, lexically rich, and developmentally attuned their language is, whether during play or other activities, and this variation cuts across cultural, socio-economic, and linguistic boundaries (Brady-Smith et al., 2013; Hirsh-Pasek, Adamson, et al., 2015; Hoff-Ginsberg, 1991; Tamis-LeMonda, Kuchirko, Luo, Escobar, & Bornstein, 2017). Consequently, enormous disparities characterize the language experiences and skills of children, already by the first and second years of life (Fernald, Marchman, & Weisleder, 2013), with differences in infancy cascading to later academic skills (Marchman & Fernald, 2008).

How can developmental science address these language gaps? And how might a focus on play empower parents to support their children's language learning? In this final part, we build on the idea that children learn language in active, engaging, meaningful, and interactive contexts – the

key elements of play (Hirsh-Pasek, Adamson, et al., 2015) – and address ways to encourage parents to be everyday play partners to their children. We acknowledge a long history of play-based intervention programs aimed at enhancing language and cognitive skills, originating with early home-based visitation programs (Andrews, 1982; Levenstein, 1970; Slaughter, 1983) and leading to current play-based interventions such as *Tools of the Mind* (Barnett et al., 2008). However, these programs focus on somewhat narrow definitions of play, and thus fall short of encompassing the range of play activities seen in children. Effective application of research on play and language requires modifying parents' and educators' perceptions about and practices around play, topics we visit next.

## *Promoting an all-inclusive view of play*

When we think of play, we often imagine blocks and dolls and trucks and toys of various types; or in the case of school-age children, costumes and board games and dashing out of class for 20 precious minutes of recess. Underlying these images is a perception of play as isolated from the ongoing activities of daily life, distinct from learning, and largely directed at manufactured toys. In reality, infants and toddlers spend much of their waking hours playing with everyday household objects like remote-controls, spoons, boxes, and shoes (Karasik, Adolph, Tamis-LeMonda, & Zuckerman, 2012), and enact elaborate pretend scenarios with whatever materials are available, for example, by spreading mud onto flat rocks to prepare pancakes or tortillas. Moreover, when presented with the option of baking real cookies, feeding real babies, and cutting real vegetables, or "pretending" to perform those tasks, U.S. 4- to 5-year-olds overwhelmingly chose to participate in the real task (Taggart, Heise, & Lillard, 2017). The choice to interact with the "real" world in "real" ways does not mean that children are not playing. Rather, play is an approach or mindset that extends to any meaningful activity with any object or person in the environment, and spans climbing up and down couches and chairs, mushing peas on a plate, reading books, and enacting routines and rituals (Chi, 2009; Hirsh-Pasek, Zosh, et al., 2015). In short, play does not require conventional "toys" and is not separate from the activities of everyday life. Returning full circle to Maria Montessori's observation – play is the work of children.

This expansive view of play advances science and practice in three fundamental ways. First, it embraces the variety of forms and materials that characterize play in cultural communities across the globe. Although toys have become emblematic of play in many communities, this may be due to the dominant focus on the experiences of children in WEIRD (Western, Educated, Industrialized, Rich, and Democratic) societies. Children in many communities around the world have little access to toys, yet creatively incorporate everyday materials into play and incorporate play into everyday activities. Developmental scientists would thus be remiss to exclude these generatively rich activities from the domain of play.

Second, an expansive view of play spotlights shortfalls in the methods researchers traditionally use to study language in the context of play. Experimenters typically seat children next to or across from caregivers, in picture-perfect positions, with a standard set of toys, and then code episodes of joint attention, contingent responsiveness, language interactions, and so forth. These structured tasks fail to capture the range of spontaneously occurring interactions during life at home – where learning actually occurs (Tamis-LeMonda et al., 2017). Naturalistic observations of children and parents are sorely needed to better understand how children play, with what and with whom they play, and how their interactions with the materials, people, and spaces of their environments promote learning.

Finally, in terms of intervention and practice, a broad definition of play shifts typical mindsets from a "learning versus play dichotomy" to a "learning through play" narrative. By changing

public perceptions about play, developmental researchers can better prepare parents and educators to recognize the opportunities for language interactions that naturally arise during everyday activities. Parents should be made aware that "talk is cheap" (Golinkoff & Hirsh-Pasek, 2012); that infants and children learn language best when actively engaged; and that play infuses an infant's day and presents an opportune context to share knowledge. In essence, play and language learning occur everywhere and at all times. Notably, these messages can be effectively communicated with basic, cost-effective reminders. Simply installing posters that prompted parents to ask children questions while shopping in a grocery store increased talk between parents and children relative to grocery stores with no posters (Ridge, Weisberg, Ilgaz, Hirsh-Pasek, & Golinkoff, 2015). This "Supermarket Study" turned an ordinary errand into an opportunity for playful learning.

Similarly, the message of "learning through play" encourages educators to value the pedagogical potential of all interactions with students, particularly those motivated by students' interests (Toub, Rajan, Golinkoff, & Hirsh-Pasek, 2016). Compared to classrooms in 1998, kindergarten classrooms in 2010 more often emphasized standardized assessments and direct instruction in literacy and math, while decreasing support of the arts, music, and child-selected activities (Bassok, Latham, & Rorem, 2016). The pressure of accountability led educators to choose "learning over play", under the misguided belief that learning is separate from play. Teachers who appreciate play's potential, and the interconnection between play and language, may be likely to involve themselves in children's play as a way to support language learning (Pyle & Alaca, 2016).

## *Promoting high-quality play interactions: striking the right balance*

One of the greatest challenges that adults face when interacting with children revolves around supporting children's autonomous discovery and initiative – often referred to as child "agency" – with just the right amount of guidance and input. The concept of child agency features prominently in theories of child development: Children actively engage with the people and materials of their environments and create opportunities for learning. This active agency is seen when infants hold out objects to adults for sharing, bring objects to others for play, and vocalize or gesture to elicit adult attention and assistance. At older ages, agency is seen when children ask questions, seek help, and keenly observe and imitate the actions of knowledgeable others. Adults who respond to their children's initiatives with topic-relevant, developmentally appropriate language support learning because – as reviewed throughout this chapter – children learn language best when adult talk focuses on the things that interest them (Konishi et al., 2014; Hirsh-Pasek et al., 2015).

However, parents and other adults vary in how much they support autonomy and how much guidance they offer their children. At one extreme, parents may leave children to learn and discover independently, providing little language input or support. If children play freely with minimal adult interaction, they will be unlikely to learn new words and concepts about objects and events, even though their actions generate a lot of perceptual information about how the world works. Much of learning will remain within children's *actual* developmental level rather than extend beyond what children can do on their own. Consequently, entirely "free play" has limited pedagogical potential.

At the other extreme, parents may unremittingly direct children's play and learning, to the point where their input is intrusive or even suffocating to children. On the face of it, high amounts of direct instruction might appear to be ideal for learning because children are exposed to words and concepts they would not otherwise encounter (Alfieri, Brooks, Aldrich, & Tenenbaum, 2011; Mayer, 2004). As one example, parents who taught children about numbers

had children who attained high scores on basic and advanced number knowledge assessments (Ramani et al., 2015). However, closer inspection revealed that parents' use of number language during playful activities mattered most. Quality in language makes the quantity work. Similarly, high maternal directiveness negatively related to preschoolers' language, reading, and math skills (Leyva, Tamis-LeMonda, Yoshikawa, Jimenez-Robbins, & Malachowski, 2017; Masur, Flynn, & Eichorst, 2005).

In short, learning is optimized when an adult follows the child's lead, and responds in developmentally appropriate ways, as echoed in Vygotsky's (1978) writings on the Zones of Proximal Development and Rogoff's (1990) concept of scaffolding. The term *guided play* captures this idea of optimal play support: The adults' role is to guide the child toward an instructional goal while maintaining the child's active role in learning (Fisher, Hirsh-Pasek, Newcombe, & Golinkoff, 2013; Haden et al., 2014; Hassinger-Das, Hirsh-Pasek, & Golinkoff, 2017; Toub et al., 2016; Weisberg, Hirsh-Pasek, & Golinkoff, 2013). Guided play is evident when parents respond to infant object exploration with lexically rich input about the target of infant attention, and when parents match their own play to the level of their child's play to guide their children to more advanced levels of play than would be possible alone (Damast, Tamis-LeMonda, & Bornstein, 1996).

However, as children enter preschool and beyond, pressure for academic achievement increases, and parents and educators may decrease their guided play, favoring direct instruction to push learning outcomes. Unfortunately, this strategy may be ineffective. In fact, classroom interventions that promoted guided play resulted in richer, child-initiated conversations and increased conversational turns, and led to more play by teachers. Consequently, evaluations of guided play curricula indicate impressive benefits for children's learning (Alfieri et al., 2011; Fisher et al., 2013), including improvements to students' vocabulary scores (Cabell, Justice, McGinty, DeCoster, & Forston, 2015; Han, Moore, Vukelich, & Buell, 2010; Hassinger-Das et al., 2016; Weisberg et al., 2015) and knowledge of geometric concepts (Fisher et al., 2013). Moreover, guided play can be effectively incorporated into ongoing curricula, with teachers presenting guided play materials in a game-like fashion (Morris, Croker, Zimmerman, Gill, & Romig, 2013; Weisberg et al., 2015). These gains occur because guided play mirrors the conditions that promote language learning (Konishi et al., 2014): Adults present high-quality language in response to the behaviors of children.

## *Summary*

The central tenet of this chapter – that play optimizes language learning – assumes that parents and educators recognize the many ways that children play and use quality language in response to children's play activities. In reality, most adults view play as a frivolous child pursuit that is limited to manufactured "toys"; consider play to be a child-only activity that is separate from the routines of everyday life; and consequently perceive a tradeoff between play and learning. We advance the view that play is an approach to learning that cuts across all activities – a perspective that has scientific and practical significance. Research on play should extend beyond structured lab tasks, beyond play with toys, and beyond WEIRD cultural communities. Interventions with parents and adults should communicate the importance of play and ways to balance instruction with support of children's agency. Yet interventions based on the principles of guided play are only recently emerging, and future research will provide valuable information on their effectiveness. Still, research to date strongly suggests that parents and educators who embrace playful learning will go far in stimulating children's language development.

## Conclusions

Infants and young children actively contribute to their language experiences by interacting with the materials, spaces, and people of their environments. During play, children have opportunities to learn the words and phrases that refer to the objects and actions of their interest. For their part, parents provide language that is lexically rich, contingent, and marked by physical cues and verbal prosody contours that mark word boundaries, elicit attention, and help infants resolve referential ambiguity. As children develop in language, play, and other cognitive skills, adults respond with increasingly complex and elaborate language, and children benefit from the unique language input that accompanies different types of play activities. The mounting evidence on the benefits of play for children's language learning counteracts the false dichotomy of "learning versus play" that pervades many communities. Rather, children learn *through* play – a message that encourages adults to appreciate and respond with high-quality language to the everyday object engagements and playful initiatives of infants, toddlers, and children. Heightened awareness of play underpins educational success stories such as *Tools of the Mind* (Bodrova & Leong, 2015), Montessori (Lillard, 2013), and guided play (Weisberg, Hirsh-Pasek, Golinkoff, Kittredge, & Klahr, 2016) curricula. Children have a lot to learn as they journey through the world of language, and certainly need not sacrifice any time for play along the way.

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# 24

# LEARNING LANGUAGE FROM BOOKS

*Elaine Reese*

> *Once upon a time there were four little Rabbits, and their names were – Flopsy, Mopsy, Cotton-tail, and Peter. They lived with their Mother in a sand-bank, underneath the root of a very big fir-tree.*
>
> *"Now, my dears," said old Mrs. Rabbit one morning, "you may go into the fields or down the lane, but don't go into Mr. McGregor's garden: your Father had an accident there; he was put in a pie by Mrs. McGregor."*
>
> *"Now run along, and don't get into mischief. I am going out."*
>
> *(Potter, 1902)*

Picturebooks contain whole worlds rich with creatures, happenings, ideas, and feelings. The illustrations in picturebooks are often easily accessible even to young children, who, when left on their own with a book, will sometimes pore over the pages and occasionally point to a familiar object or animal and exclaim its label. Yet most of the knowledge contained in picturebooks is not accessible to young children without the help of a patient and creative reader who can, through language, reveal the world within the book for the child, and encourage the child to enter that world. For instance, to enter the magical world of *Peter Rabbit*, the child may need for the reader to explain how rabbits live in burrows; why they like to visit gardens; why (in the past) they might have been baked into a pie; and what the words "lane" and "mischief" mean.

Conceivably, the worlds contained in picturebooks can offer children opportunities to learn new words describing animate and inanimate objects, actions, and mental states, at least some of which are outside the realm of children's real-world experiences. The text of picturebooks is also cast in more complex language than is present in the world of everyday speech for young children (Montag, Jones, & Smith, 2015), potentially providing a chance to learn advanced grammatical forms. Many picturebooks contain dense amounts of rhyme, alliteration, and other language features that could promote children's phonological awareness. Finally, narrative picturebooks contain well-structured stories with a beginning, a problem that is developed, and a resolution, affording children a chance to acquire canonical narrative forms.

In this review, I first establish the significance of picturebooks for all of these aspects of young children's language learning – vocabulary, syntax, phonological awareness, and narrative. Then I detail how readers (typically adults) can engage children in the world of picturebooks

in ways that optimize their language learning, updating a model of the factors contributing to high-quality picturebook reading (Fletcher & Reese, 2005). I conclude by posing unanswered questions in the research on picturebooks and children's language development.

## A very brief history of picturebooks for young children

It is clear that picturebooks are not essential for young children's language learning. Although the first illustrated book aimed specifically at young children was published in 1744, children's picturebooks became widely available only in the last 100 or so years, and only in educated Western strata (see Kiefer, 2011; Kummerling-Meibauer, 2018). Even today, picturebooks are rare in some countries and cultures and social classes (e.g., in developing countries such as Bangladesh, see Opel, Ameer, & Aboud, 2009; and in Spanish-speaking Hispanic families in the U.S., see Raikes et al., 2006). Yet children the world over learn to speak. Thus, picturebooks are certainly not necessary for children's language learning, but as I will argue in this review, picturebooks are an especially nice way to advance many aspects of oral language acquisition. Under certain conditions, picturebooks can also be used effectively to teach children to become literate users of the written word (e.g., Piasta, Justice, McGinty, & Kaderavek, 2012; see Mol, Bus, & de Jong, 2009 for a meta-analysis); however, my focus here is on oral language. Moreover, most of the research on this topic has been conducted with monolingual English speakers and picturebooks written in English; below I note the exceptions to this rule when they occur.

## Quantity of picturebook reading and young children's language development

To what extent do young children learn oral language skills from picturebooks? Fortunately, several meta-analyses and integrated reviews have been conducted to assess the strength of the association between parent-child book-reading and children's language development (e.g., Bus, van IJzendoorn, & Pellegrini, 1995; Scarborough & Dobrich, 1994). These reviews were based primarily on correlational research that tracked the reported *quantity* or frequency of book-reading in the household in relation to children's language development, sometimes over time. Most often, parents were asked simply to estimate the frequency with which they read books with their young children in a typical week, from not at all to monthly, weekly, daily, or more often (Scarborough, Dobrich, & Hager, 1991). Given that reading books with young children is now seen as a socially desirable activity, frequently touted as one of the most important activities parents can engage in with their children (Joyce, 2017), it may be difficult for parents to answer this question honestly. Yet in the 1960s, 1970s, and 1980s when most of the research was conducted on which these reviews are based, picturebook reading did not have quite the social currency that it now enjoys, and parents did answer this question with a range of responses. For instance, only around 50% of the middle-class mothers in Scarborough et al. (1991) reported that they read to their 3-year-old children on a daily basis. The main finding from these reviews was that frequency of picturebook reading contributes moderately to children's language development. For instance, Bus et al. estimated an average effect size across studies of $d = 0.67$ between frequency of picturebook reading in the home and children's oral language development, broadly conceived. In a similar vein, Scarborough and Dobrich concluded that the median correlation coefficient between book-reading frequency and lexical/semantic aspects of language was .26, and between book-reading frequency and syntactic and phonological aspects of language was .17. A more recent study with a large, representative sample of Australian children born in the early 2000s documented the same correlation ($r = .26$) between parents' reported quantity of shared

book-reading (a duration measure of number of minutes per day) between 9 and 34 months and children's expressive vocabulary at 34 months (Farrant & Zubrick, 2012). In that study, shared book-reading uniquely accounted for 5% of the variance in expressive vocabulary after controlling for earlier vocabulary, child gender, temperament, socio-economic status (SES), number of siblings, household income, maternal education, and parenting warmth. Thus, contemporary findings of the link between book-reading frequency and children's language continue to show a moderate role for the quantity of shared book-reading in children's language development.

An important limitation of these correlational studies, however, is the degree to which shared book-reading alone is associated with children's language. It is probable that parents who are frequently reading books with their young children are also engaging in other activities that support children's language learning (see Chapter 23, this volume). These reviews of correlational studies do not allow us to identify the unique contribution of book-reading compared to other naturally occurring parent-child interactions. Thus, these estimates are most likely overestimates of the specific contribution of book-reading to children's language learning. In contrast, experimental studies of the effects of different styles of shared book-reading offer a view of the *potential* benefits for children's language under ideal conditions (see Flack, Field, & Horst, 2018, for a meta-analysis). I will attempt to integrate information from these two approaches throughout this review.

Another limitation of these large correlational studies and comprehensive reviews is that they do not address which aspects of children's oral language are supported by adult-child book-reading. Typically, in these studies of book-reading frequency, there is only a single measure of children's language, most often a single measure of receptive vocabulary – such as the Peabody Picture Vocabulary Test (PPVT; Dunn & Dunn, 1997) – and less often a more comprehensive measure of language development such as the Preschool Language Scales (PLS; Zimmerman, Steiner, & Pond, 1992) or a measure of syntax (*Test for Auditory Comprehension of Language*, TACL; Carrow-Woolfolk, 1999a, b). Sometimes the measure of language development is a parent report scale, such as the Communicative, Social, and Behavior Scales (CSBS; Wetherby & Prizant, 2002) or the MacArthur Communicative Development Inventories (MCDI; Fenson et al., 1994). Thus, these studies cannot specify which aspects of language development – word learning, syntax, phonology, narrative – are most strongly associated with picturebook reading, or indeed if all of these aspects of oral language are supported equally and simultaneously. One notable exception is a study by Sénéchal, Pagan, Lever, and Ouellette (2008), who estimated book-reading frequency using parent reports and author checklists, and then assessed preschool children's expressive vocabulary, morphological comprehension, syntax comprehension, and narrative production skills. Control variables included parent education and children's nonverbal intelligence. Shared book-reading uniquely accounted for 10% of the variance in children's expressive vocabulary and 7% of the variance in their morphological comprehension, yet there was no positive association between shared book-reading and children's narrative production skills. There was a significant association between shared book-reading and children's syntax comprehension, but this association was mediated by parents' own reading practices, such that shared book-reading predicted syntax only for children of parents who read more books themselves. The authors suggested that this mediation effect could be due to differences in the picturebooks they selected to read with their children, with more literate parents selecting books with more sophisticated language for their children, and/or to different ways that more literate parents read with their children. This insight is supported by the research on quality of picturebook reading, to which I turn next.

## Quality of picturebook reading and young children's language development

Observational research in the 1980s and 1990s revealed that there is a multitude of ways that adults can share a picturebook with young children. This research relies on recording adults and children sharing picturebooks, with the picturebook often supplied by the researcher to ensure novelty and comparability across dyads, or sometimes selected by the parent or teacher as a familiar favorite. The interactions are then transcribed, and any departures from the reading of the text (extratextual talk) are coded and analyzed. For some parents and teachers, the focus is squarely on the *reading* of the text, which Dickinson and Smith (1994) referred to as a *didactic* style, and which in contemporary terms would be called a non-interactive style. These parents and teachers read the book virtually straight through without stopping. If children ask a question or point to a picture during the reading, these adults will sometimes briefly answer the question but at other times will ignore or quickly dismiss the child's question, clearly viewing any interaction as an interruption to the task at hand. The few questions adults do ask are about immediate recall of the text. A very different style of sharing books is what Dickinson and Smith called a *performance-oriented style*. This style, which may be more common among teachers than parents, also involves reading the text with few interruptions, but in a highly dramatic fashion, employing character voices and pauses for dramatic effect. A critical difference to the didactic style is that after the reading, these teachers have extended and analytical discussions of the book. In contemporary terms, the performance-oriented style would be considered interactive (see Gonzalez et al., 2014), but only if researchers included the pre- and post-reading discussions in their recording and analyses.

Other parents and teachers encourage interaction throughout the reading of the book with a third *co-constructed style* of book sharing (Dickinson & Smith, 1994), which in contemporary terms would be called simply an interactive style. If a child asks a question about a picture, they answer the child's question and then elaborate, and they often comment upon and initiate questions about the storyline or about the pictures. These adults seem to view the picturebook as a springboard for conversation. Yet even within this interactive style, there are differences in the content and form of the interaction (e.g., Haden, Reese, & Fivush, 1996; van Kleeck, Gillam, Hamilton, & McGrath, 1997). Some parents and teachers focus primarily on less demanding questions about the pictures (e.g., descriptions and labels) that do not require any inferential thinking. Other parents and teachers also use these lower-level literal questions, but supplement them with more demanding questions and conversations about print concepts, why characters engaged in certain actions or felt particular emotions, what might happen next in the story, and what experiences the child might have had in real life that link to the story, or, more rarely, they define new words (Hindman, Skibbe, & Foster, 2014).

McNaughton (1995) identified a fourth *recitation style*, prominent among Pacific Island and Māori parents in New Zealand, in which the adult reads the text and then asks the child to repeat the text, utterance by utterance. The goal of this style seems to be for the child to memorize the text in order to reproduce it orally; oral recitation is a common practice in these cultures. In small sample studies, researchers have continued to document cultural differences in book-reading styles. For instance, Hammer, Nimmo, Cohen, Draheim, and Johnson (2005) found that African-American mothers were more likely to simply read the text compared to Puerto Rican mothers, who were more likely to adopt a child-centered style in which children were encouraged to tell the story largely independently, assisted by the mothers' questions only when needed. However, in a large-scale nationally representative study of ethnically diverse,

low-income U.S. mothers, Hindman et al. (2014) identified no reliable ethnic differences in mothers' book-reading styles once their education level was covaried.

Thus, this early work identified individual differences in parents' and teachers' reading styles. Adults differ dramatically in their overall level of interaction during the reading session. For adults who do adopt an interactive style, they differ in the content of the interaction, from a primarily literal focus to a more inferential one. Once these individual differences were documented in the ways adults shared picturebooks with young children, the research turned primarily to studying the effects of these different interaction styles for children's language and literacy. The ultimate goal has been to improve the quality of the book-reading experience for children. Below, I will review this research on the quality of book-reading and each aspect of oral language development in turn: vocabulary, syntax, phonological awareness, and narrative. These studies of interaction quality have drawn upon a plethora of designs: correlational (both concurrent and longitudinal) and experimental (both short-term experiments and longitudinal interventions); all have tested the association between adult-child book-reading and various aspects of children's language development. These studies still often include a measure of the frequency or quantity of book-reading, but the main focus is on the strategies that adults use to engage children with the picturebook.

## *Book-reading and vocabulary development*

The bulk of the research on links between book-reading and children's oral language development has addressed children's learning of new words from picturebooks. The reasons are most likely twofold: first, picturebooks contain greater lexical diversity and a larger number of rare words compared to everyday speech to young children, so they afford a rich context for vocabulary acquisition (Montag et al., 2015); and, second, measuring children's acquisition of new words from books is arguably easier than measuring their acquisition of higher-order language development, especially syntax and narrative. Measuring syntax and narrative acquisition almost always requires recording, transcribing, and analyzing speech samples – a laborious enterprise. A final reason for the recent focus specifically on low-income children's word learning from picturebooks has been the emphasis on the word gap between low-income and middle-income children (see Hart & Risley, 1995; Snell, Hindman, & Wasik, 2015). Although there are almost certainly "syntax gaps" and "narrative gaps" as well between low-income and middle-income children, these other dimensions have so far been neglected in favor of the vocabulary gap. But regardless of the reasons for this focus on the lexicon, the field now offers a broad and deep understanding of how – and how often – children acquire new words from picturebooks.

Much of this research on the quality of book-reading in relation to children's vocabulary development is correlational, mapping individual differences in parents' and teachers' book-reading styles in relation to children's vocabulary development. The vocabulary measure in these studies is typically a standardized measure of receptive or expressive vocabulary, such as the Peabody Picture Vocabulary Test (PPVT; Dunn & Dunn, 1997), the Expressive Vocabulary Test (EVT; Williams, 1997), or the MacArthur Communicative Development Inventories (MCDI: Fenson et al., 1994). For instance, mothers who adopted an interactive and high-level *comprehender style* of reading had children with larger receptive vocabularies over time (Haden et al., 1996), and teachers who adopted a high-level performance-oriented style of reading had children in their classrooms who grew more in their receptive vocabularies over the school year (Dickinson & Smith, 1994).

In studies that explore the potential mechanism of these effects in terms of specific strategies associated with word learning from picturebooks, it is clear that adults' low-level comments

and questions (labels, descriptions, text recall) are consistently linked concurrently to preschool children's smaller vocabularies (e.g., Hindman, Wasik, & Erhart, 2012; Robertson & Reese, 2017; van Kleeck et al., 1997). In contrast, high-level talk during book-reading (inferences, relating to the child's world) is consistently linked to children's larger vocabularies (e.g., Britto & Brooks-Gunn, 2001; Haden et al., 1996; Hindman, Connor, Jewkes, & Morrison, 2008; Hindman et al., 2012; Tompkins, Bengochea, Nicol, & Justice, 2017; van Kleeck et al., 1997, 2006; Zucker, Justice, Piasta, & Kaderavek, 2010). Yet van Kleeck et al. showed that both low-level and high-level utterances were positively correlated with children's *growth* in language over time. This result indicates that low-level utterances may be important for initially engaging younger and less linguistically advanced children in shared book-reading, and high-level utterances more important for challenging older and more linguistically advanced children. Reese and Cox (1999) confirmed these moderating effects experimentally for 4-year-old children's vocabulary by contrasting a higher-level performance-oriented style (with interaction before and after the reading) with a lower-level describer style (with interaction throughout the reading). The describer style was more beneficial for younger and less advanced children's vocabulary, whereas the performance-oriented style was more beneficial for older and more advanced children's vocabulary (see also Wasik, Bond, & Hindman, 2006, for a similar finding). Moreover, two studies with preschool teachers also show a moderating role for children's initial skill level, such that children starting out with higher vocabularies showed greater growth when teachers used more high-level talk, and children starting out with lower vocabularies showed greater growth when teachers used more low-level talk during book-reading (Hindman et al., 2008; Zucker et al., 2010).

New work with preschool teachers in Head Start settings identifies the content, form, and linguistic features of teachers' extratextual talk during picturebook reading that supports children's word learning (Barnes & Dickinson, 2017a; Barnes, Dickinson, & Grifenhagen, 2017). During book-reading, teachers who commented more during the reading, were more responsive to children's utterances, and included more lexical elements (types, tokens, sophisticated vocabulary) had students with greater vocabulary growth over the year. Children with lower language levels benefited least from teachers' comments, in line with the moderator effects already identified. In these classrooms with 4-year-old children who on average scored below the mean on a standardized language test (82 on the PPVT), teachers' comments that were medium-level (explain/define/recall), not high-level or low-level, were most strongly associated with children's vocabulary growth (Barnes & Dickinson, 2017b). New work with mothers also identifies particular kinds of inferential comments (yes-no questions and statements) as being supportive for older preschoolers' vocabulary growth (Tompkins et al., 2017). Tompkins et al. argued that mothers are providing children with correct information in their yes-no questions and statements, and that children need this information to benefit from these more difficult comments.

The remaining research on this question is experimental, ranging from short-term experiments of the acquisition of new words from books as a function of different questioning styles, to long-term interventions comparing a best-practice form of interactive reading with typical reading. Some of this experimental research is based on researcher-created picturebooks as opposed to commercially available picturebooks in order to strictly control the administration and placement of the new words (e.g., Horst, Parsons, & Bryan, 2011). I consider research from both researcher-created and artist-created books to be useful for understanding the way that children learn new words from books.

The authors of a systematic review of high-quality experimental studies of children's word learning from researcher-created and commercially available books (Wasik, Hindman, & Snell,

2016), however, concluded that children's acquisition of new words from picturebooks is modest. Some of these studies were of *dialogic reading*, a popular form of highly interactive picturebook reading, relying on repeated readings, with documented benefits for children's expressive vocabulary (e.g., Whitehurst et al., 1988; see meta-analyses by Mol, Bus, de Jong, & Smeets, 2008; Mol et al., 2009, for similar conclusions). Only studies that included an alternate-treatment control group were included in the meta-analysis, and not studies that compared an experimental form of reading to a no-treatment control group. Included studies almost all contained a measure of children's acquisition of target words from the books (e.g., Blewitt, Rump, Shealy, & Cook, 2009; but cf. Whitehurst, Arnold, et al., 1994). On average, children's learning of new words from picturebooks was significant but minimal, even after repeated exposures. For instance, in Lever and Sénéchal's (2011) dialogic reading study, children in the target group were able to produce a label for only 2 out of the 16 new words presented, compared to an alternate-treatment group's mean of 1 of the 16 words at post-test. However, once the word was learned, the 11 out of 31 studies that included a follow-up test showed that children did maintain that word knowledge over weeks and months (Wasik et al., 2016). Children need many exposures to learn new words from picturebooks, delivered and discussed in high-quality ways by adults. Most importantly, without adult-child interaction, Wasik et al. noted, children's acquisition of new words from the same picturebooks was nearly at chance levels. This overall effect is less impressive than many researchers, and perhaps the general public, seem to assume.

One reason for these modest effects could be that the Wasik et al. (2016) review did not differentiate children's word comprehension and production outcomes. In a meta-analysis of high-quality experimental book-reading studies focusing only on comprehension outcomes, Flack et al. (2018) instead demonstrated that children learn nearly half of the new words (46%) to which they are exposed. Similar to Wasik et al.'s conclusions, Flack et al. found that children's word learning is greater when adults interact during the reading rather than simply reading the text, and when children hear the new words repeatedly.

Another reason for the difficulty of learning new words from books is due to the representational challenges for young children inherent in the two-dimensional nature of picturebooks (cf. Chapter 25, this volume). The objects represented on the pages cannot be held or rotated, and actions are static. Moreover, the exemplar of the referent is necessarily limited; the yellow duck on the page bears little resemblance to the Muscovy duck the child sees at the local pond, rendering generalization difficult. Experimental research using researcher-created books sheds light on this issue. For younger children (below 2 years), photos and realistic drawings in picturebooks foster word learning over cartoon drawings of the same objects (Ganea, Pickard, & DeLoache, 2008). Toddlers also learn new words faster when adults gesture to the pictured object while labeling it (Rohlfing, Grimminger, & Nachtigäller, 2015). Simply put, children need extra interactions with adults in order to learn new words from picturebooks.

The finely crafted short-term experimental work with researcher-created books also identifies the mechanisms by which children learn new words from picturebooks. These studies all manipulate specific features of the words, the books, and the interaction style to discover the optimal way for children to learn new words. These studies reveal that repeated readings (e.g., Horst et al., 2011), casting the interaction about the new word into an open-ended question rather than a simple label (e.g., Blewitt & Langan, 2016), and confirming and elaborating upon the child's response to the question (e.g., Blewitt & Langan, 2016) all support the acquisition of new words. Moreover, the same text rewritten in rhyming form as opposed to prose helps children retain new words, perhaps because parents tend to pause before saying the target word when reading the rhyming text, making it more salient for children (Read, Macauley, & Furay, 2014). In short, high-quality adult-child interaction that encourages children to actively use

the new words, and that confirms and expands upon children's responses in a sensitive and contingent way, supports learning of new words from books, just as these input features support children's learning of new words from everyday speech (Hoff, 2006).

## Book-reading and syntax development

In contrast to vocabulary development, very few studies have been conducted on children's acquisition of new grammatical forms from picturebook reading. This dearth of research is surprising given that one of the oft-touted features of picturebooks is that the text contains more complex language than is available in everyday speech for young children (Montag et al., 2015). Most likely, this oversight is due to the greater difficulty of measuring syntax compared to vocabulary. Nevertheless, the few studies that do exist all suggest that children do learn new grammatical forms from interactions with picturebooks, but that these effects are somewhat smaller and more fragile than those for word learning. For instance, in a correlational study, Sénéchal et al. (2008) found that parents' book-reading frequency predicted 7% of children's morphological skills on the Grammatical Morphemes subtest of the *Test for Auditory Comprehension of Language* (Carrow-Woolfolk, 1999b). Shared book-reading frequency also predicted children's syntax skills, but only for children whose parents read more themselves, which could suggest a difference in the quality of extratextual talk among those parents. In the first dialogic reading study with middle-class parents of 2-year-olds, Whitehurst et al. (1988) showed that children in the dialogic reading group later used more phrases and fewer single words, and had a higher mean length of utterance (MLU) compared to children in the typical reading group. However, in a dialogic reading study with teachers and low-income 3- and 4-year-olds, the children's MLU increased as a function of dialogic reading only in centers rated as high in compliance to the dialogic reading regimen (with an effect size of 0.63) as opposed to low in compliance (effect size of 0.19). Thus, the dosage, and possibly the quality, of dialogic reading matters for children's syntax development, suggesting that it is the adult-child interaction that is helping children's syntax, and not the complex text of the book per se. In fact, a recent study demonstrated that simple texts elicit extratextual talk from parents that is more grammatically complex – as defined by their subject-predicate clauses and complex sentences – compared to more complex texts (Noble, Cameron-Faulkner, & Lieven, 2017).

## Book-reading and phonological awareness development

Similar to syntax development, very little research exists on the benefits of book-reading for children's phonological awareness. Again, this absence is surprising given the popularity of commercially available picturebooks featuring rhyme and other soundplay (see Children's Books Guide, 2013). An early experimental study demonstrated that casting the same book in rhyming versus non-rhyming language facilitated preschool children's scores on a rhyme-alliteration task (Hayes, 2001). Dialogic reading with Arabic-speaking kindergarteners enhanced their phonological awareness in comparison to the typical kindergarten curriculum (Elmonayer, 2013). Early correlational studies conducted with narrative picturebooks (presumably mostly in prose, but text style is typically unspecified in these studies) do not show an association between the quantity or quality of book-reading and children's phonological awareness (e.g., Sénéchal & LeFevre, 2002). However, more recent research that carefully contrasts rhyming to prose books (both narrative) shows that parents' comments about word sounds and print are more common in rhyming compared to prose books (Riordan, Reese, Schaughency, & Rouse, 2018). Moreover, these parental comments about sounds and print (only in the rhyming book) are linked to

children's phonological awareness. This effect was moderated by children's age, such that older preschoolers benefited more from these comments about sounds and print than did younger preschoolers.

## *Book-reading and narrative development*

A moderate amount of research has focused on children's acquisition of narrative skills from picturebooks, in terms of both their understanding of the story and their ability to retell the story from the book they heard, or to produce new stories. The correlational research reveals once again that when adults ask higher-level inferential questions about the story, children have better story comprehension skills (e.g., Robertson & Reese, 2017). The experimental research sometimes compares the picturebook context to other storytelling contexts, such as hearing stories about past events (reminiscing; e.g., Reese, Leyva, Sparks, & Grolnick, 2010) or engaging in story-acting/storytelling activities (Nicolopoulou, Cortina, Ilgaz, Cates, & de Sá, 2015), for their differential effects on children's narrative skills. Most of this experimental research has been conducted in preschool settings, with either teachers or researchers leading the storytelling. Pesco and Gagné (2017) conducted a meta-analysis of these experimental designs in preschool settings, restricting their analysis to high-quality studies employing random assignment to conditions, excluding studies that included only a single narrative treatment group compared to a no-treatment control group. Across the final set of 15 studies, the main finding was that adults' extratextual talk (termed "verbal scaffolding") during and after picturebook reading fostered children's narrative comprehension and production, with a medium-sized effect. Neither the timing of the extratextual talk (during book-reading or after) nor the duration of the instructional sessions moderated the effect, but the inclusion of nonverbal activities (props, acting out the story afterwards) strengthened the effects. Thus, interactive reading in preschool settings boosts children's narrative skills, over and above their mere exposure to hearing stories from picturebooks, especially if the reading is accompanied by nonverbal activities that support the storytelling.

Other research on the narrative benefits of picturebooks has been conducted with parents, primarily low-income parents. For instance, with low-income families in Israel, Aram, Fine, and Ziv (2013) compared two book-reading conditions: one in which parents were taught to read four new picturebooks four times each, first focusing on the plot of the story, second focusing on the characters' mental states, third focusing on linking to the child's own mental states, and on the final reading encouraging the child to tell the story independently. In the control condition, mothers and children received the same new books, and weekly home visits by a researcher who asked about their enjoyment of the books, but did not learn specific techniques for extratextual talk. After the intervention, mothers and children in the experimental group talked more about the plot and sociocognitive themes of a wordless picturebook, with children also using more mental state terms. In contrast, also working with a sample of low-income parents whose 4-year-old children were attending Head Start in the U.S., my colleagues and I compared dialogic reading to a conversational storytelling condition without books (reminiscing about past events) and to a no-treatment control condition (Reese et al., 2010). For this sample of parents, who may not have been as comfortable reading books together as they were with reminiscing, the reminiscing condition was more effective than dialogic reading for promoting the quality of the narratives children retold from books 6 months after parents were taught the techniques, controlling for children's pre-test narrative skills. Our training of parents in dialogic reading focused on the PEER sequence (Prompt-Evaluate-Expand-Repeat), however, and not specifically on narrative elements of the story. Thus, to effectively promote children's narrative

development through picturebook reading, low-income parents may need specific coaching in how to talk about plot and emotions during the story reading.

### *Summary of book-reading quality and oral language development*

To summarize across these dimensions of children's oral language development, a robust finding is that more interactive reading sessions, in which adults engage in explicit and responsive conversations that encourage children's active participation, are best for children's language development. Children simply do not learn as much from books when adults merely read the text and do not encourage interaction (see Flack et al., 2018). Although some studies with older children sometimes revealed benefits of a style that did not interrupt the text (e.g., the performance-oriented style; Dickinson & Smith, 1994; Reese & Cox, 1999), that style was still interactive – with high-level interactions occurring after the reading of the text. The little experimental research that has been conducted with bilingual children learning English as a second language, or with monolingual children learning non-English languages, shows the same basic findings (e.g., Aram et al., 2013, with Hebrew-speaking children; Collins, 2010, with English-Portuguese bilinguals; Opel et al., 2009, with Bangladeshi-speaking children; Simsek & Erdogan, 2015, with Turkish-speaking children).

Now that the benefits of extratextual talk have been well established for children's vocabulary and narrative skills, it is time for researchers to study the moderators of those effects, such as the cognitive and linguistic skills of the children in relation to the timing of talk. This information will enable researchers to offer more tailored advice to teachers and parents about the book-reading techniques that are likely to work best for their children. For instance, the effect of the optimal timing of the interaction, whether during or after the book-reading, is still open to debate. There is some indication that older and more advanced preschoolers benefit more in their word learning from discussions about the book that take place after the reading has finished (Gonzalez et al., 2014; Reese & Cox, 1999), perhaps because the storyline is not interrupted. With a sample of middle-class preschoolers, however, Jimenez and Saylor (2017) found that whereas all the children learned words from discussions after the book-reading had finished, only the children with stronger short-term memory skills were able to learn new words from discussions *during* the reading. They concluded that the cognitive load of focusing on the storyline and discussing new words simultaneously was too great for children with poorer memory skills. Moreover, in their meta-analysis, Pesco and Gagné (2017) did not identify the timing of the interaction to matter for children's narrative outcomes. Ideally, new research would also be conducted on the benefits of extratextual talk during picturebook reading for children's syntax and their phonological awareness. What if the timing of the talk is even more crucial for children's syntax and phonological development, such that it is best for older children to hear the book uninterrupted so that they can focus on the sounds of the complex language of the text? Most likely, what will emerge is not a unitary style of book-reading that is best for all children and for all aspects of language development, but specific styles that are matched to children's characteristics and skills and to the aspect of language being fostered.

## Factors affecting book-reading interactions: an updated model

What we do know from the research conducted so far is that high-quality book-reading is interactive and sensitive to children's questions and responses. What are the factors that support parents and teachers in adopting a high-quality style of reading? In 2005, Kathryn Fletcher and I proposed a model of the factors affecting the quality of book-reading with young children

(under 3 years old), based on the extant research. With the huge number of studies on picturebook reading conducted since 2005, it is time to revisit and update our model. In the original model (see Fletcher & Reese, 2005, Figure 20.1), we proposed that high-quality picturebook reading with young children was a function of adult reader factors (SES, sex, culture), child factors (language level, attention/interest, attachment security), and book factors (repeated readings, type/genre, complexity, frequency). New research on book-reading quality has been conducted since that time on all of these factors, with the possible exception of attachment security, for which my search turned up no new research. Moreover, new factors have been identified as important for book-reading quality since that time. Figure 24.1 lists all of these factors, with the new factors noted in bold-faced type. Note that I have not included children's gender as a factor affecting quality. Although some new research has identified that parents read more often and for longer to their female than male toddlers (Baker & Milligan, 2016; Duursma, Pan, & Raikes, 2008; but see Farrant & Zubrick, 2012), no research to my knowledge has found differences in the *quality* of book-reading with girls and boys. Also note that I have extended the model to include research with older preschoolers in order to be more comprehensive in scope.

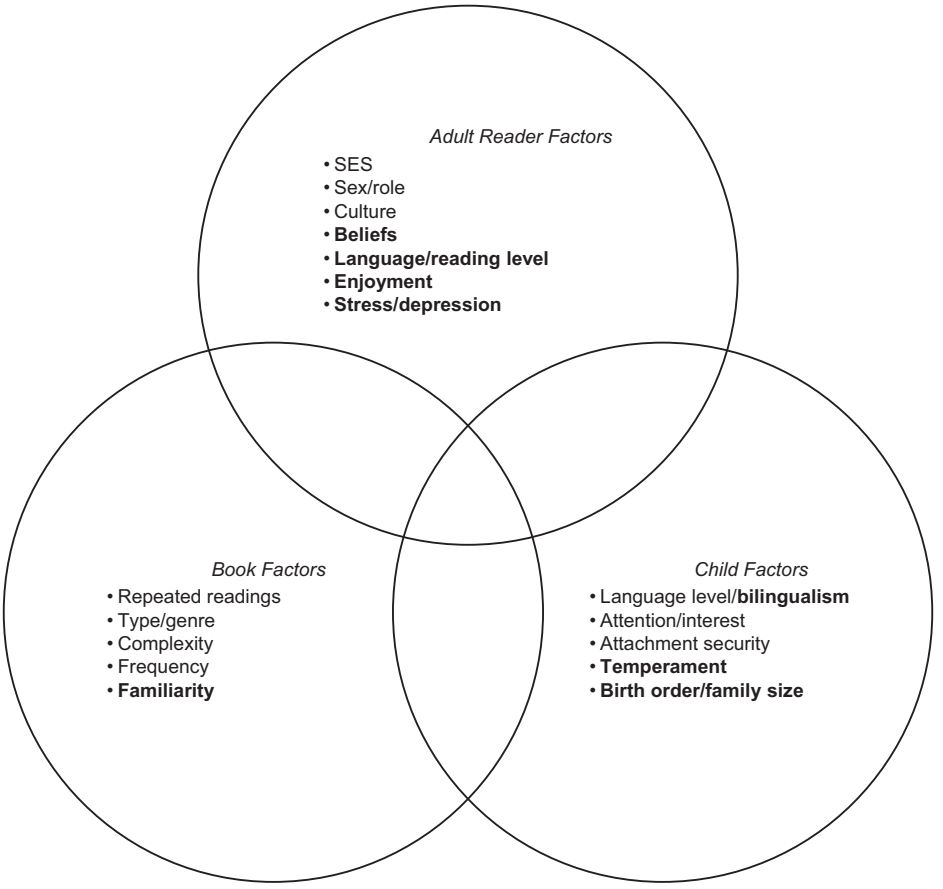



*Figure 24.1* Quality of picturebook reading with young children.

Below I discuss new research since the Fletcher and Reese (2005) review that has been conducted on each of the factors in turn. It is not a comprehensive review, which is beyond the scope of this chapter. Instead, I have selected representative new studies that illustrate the main findings.

## *Adult reader factors*

### *SES*

With the publicity about the word gap, there has been a huge number of new studies conducted with low-income families. In fact, most of the new research is with low-income families and with teachers of low-income children (e.g., Nicolopoulou et al., 2015; Raikes et al., 2006). However, only a few studies have examined a broad range of SES in relation to book-reading quality. For instance, Kucirkova, Dale, and Sylva (2018) found that higher SES parents in the UK shared picturebooks with their 10-month-olds in a higher quality way (defined as providing language stimulation and emotional support) than lower SES parents. Parents' SES remained a unique predictor after controlling for the parent-child relationship and children's temperament.

### *Sex/role*

The main development here has been a welcome focus on fathers' book-reading with their young children. These studies are primarily based, however, on two low-income samples, so caution is needed in interpreting the generalizability of these effects. For instance, with an Early Head Start sample, fathers read regularly to their children, but less frequently than did their partners (Duursma et al., 2008). When fathers were observed reading books with their children, they engaged in more high-level extratextual talk than did mothers (Duursma, 2016; Malin, Cabrera, & Rowe, 2014); however, mothers and fathers read different books in this observation, so these differences in extratextual talk could instead be due to the book. With a low-income rural sample, Pancsofar, Vernon-Feagans, & Family Life Project Investigators (2010) and Baker and Vernon-Feagans (2015) found that mothers and fathers were largely similar in their book-reading quality during wordless picturebook interactions at 6 and 60 months in terms of diverse vocabulary and MLU. However, only fathers' language during the book-reading sessions, and not mothers' language, predicted children's later language. This finding is intriguing but needs to be replicated with other samples and with texted picturebooks. Finally, with a middle-class New Zealand European sample, Robertson and Reese (2017) noted that at least some fathers are the primary readers in the household with their preschool children (36% of our community sample). Once mothers' and fathers' reading frequency was matched, there was no difference in quantity or quality of extratextual talk between mothers and fathers when reading either a narrative or an expository book.

### *Culture*

Surprisingly little new research has been conducted on the role of culture in book-reading styles, most likely because the emphasis has instead been on low-income children of diverse ethnicities. The few studies conducted suggest that African-American mothers prefer to focus on reading the text compared to Puerto-Rican mothers (Hammer et al., 2005) and that African-American mothers produce more high-level speech when engaged in oral storytelling with their children compared to picturebook reading (Curenton, Craig, & Flanigan, 2008). However,

in a large-scale representative U.S. sample, Hindman et al. (2014) noted no reliable ethnic differences among low-income mothers' reading styles.

### *Beliefs*

Similar to culture, little new research has been conducted on parental beliefs and the quality of picturebook reading, but these new results are in the expected direction. For instance, Bojczyk, Davis, and Rana (2016) found that low-income parents who believed that book-reading should be more interactive were indeed more interactive when observed reading a picturebook with their children. Observed interaction quality completely mediated the link between parental beliefs and children's expressive vocabulary, suggesting that it is the way parents are interacting that matters most for children's language, but their beliefs may be shaping those interaction patterns.

### *Own language/reading level*

The little research available on this factor suggests that Spanish-speaking parents in the U.S. do not report reading as often with their young children as do English-speaking parents (e.g., Raikes et al., 2006; Duursma et al., 2008). This difference can be attributed, at least in part, to the lack of availability of picturebooks in non-English languages.

### *Enjoyment*

My search turned up no new evidence that parents' enjoyment of reading was linked to the quality of their book-reading. For instance, Robertson and Reese (2017) asked parents to rate their enjoyment of reading fiction versus non-fiction in their own reading. Mothers reported preferring to read fiction, and fathers reported preferring to read non-fiction books, but mothers and fathers did not differ in their enjoyment or quality of reading narrative or expository books with their young children.

### *Stress/depression*

Similarly, I could not find any new studies of parental stress/depression and the quality of book-reading. Paulson, Dauber, and Leiferman (2006) noted that mothers reported reading less often with their infants when either they or their partners were depressed, but did not assess the quality of the interactions.

## ***Child factors***

### *Language level and bilingualism*

As foreshadowed above, high-quality book-reading takes on a slightly different form when children are younger and less advanced linguistically. New research in this regard suggests that teachers' use of less complex speech (shorter MLU) during book-reading is better for vocabulary growth when children have lower language levels (Barnes & Dickinson, 2017b). However, this was a correlational study, and children's language level was not examined as a moderator of the association.

Several new studies suggest that dialogic or interactive reading with bilingual children has similar positive effects to interactive reading with monolingual children. For instance, with a very small sample of 12 English-Spanish bilingual toddlers with expressive language delays, Tsybina and Eriks-Brophy (2010) found that a 6-week dialogic reading intervention in both English (researcher-led) and Spanish (mother-led) helped children learn target words in both languages (but led to no overall expressive language gains) compared to a delayed-treatment control group. Effect sizes for target words in both languages were large. Collins (2010) showed that rich explanation compared to non-interactive story reading helped bilingual English-Portuguese children learn new English words. Finally, a new meta-analysis of shared book-reading interventions (broadly conceived) identified a positive effect for subsamples of English language learners (Fitton, McIlraith, & Wood, 2018).

## *Attention/interest*

Two large new studies have identified the importance of children's attention and interest in book-reading interactions. For instance, Farrant and Zubrick (2012) found that children's greater joint attention in everyday interactions at 9 months predicted longer reported duration of parent-child book-reading sessions between 9 and 34 months. Duration may be seen as a proxy measure of quality given that longer book-reading sessions are typically more interactive. Moreover, Malin et al. (2014) found an association between children's interest in book-reading sessions and parents' high-level (metalingual) talk. In fact, children's interest mediated the link between parents' metalingual talk and children's receptive vocabulary.

## *Attachment security*

My search of the literature turned up no new studies since our 2005 review of the role of children's attachment security per se, but if broadened out to the affective quality of the parent-child interaction, then several new studies are relevant. For instance, Kucirkova et al. (2018) found that a positive parent-child relationship predicted high-quality book-reading among UK 10-month-olds, even after controlling for parents' SES and children's temperament. Moreover, Landry et al. (2012) showed that a Play and Learning Strategies (PALS) intervention to encourage sensitive and responsive parenting produced later changes in the quality of shared book-reading, even without specific training in book-reading. Higher doses of PALS – receipt of the intervention at both infancy and toddlerhood – were linked to greater increases in mothers' supportive verbal behaviors during book-reading (open-ended prompts, assists, lead-ins, expansions, praise and encouragement). Therefore, although it may not be necessary to specifically target book-reading in order to increase the quality of the interaction, a large dose of a more general parenting intervention may be needed in order for mothers to generalize these speech patterns to the book-reading context.

## *Temperament*

Since Fletcher and Reese (2005), several new studies have explored the role of children's temperament in shaping the quantity and quality of book-reading interactions. Intriguingly, the findings all run counter to our initial predictions that book-reading quality would be higher with children with less difficult temperaments. For instance, Kucirkova et al. (2018) found that 10-month-old infants' unsociable temperament predicted higher quality reading interactions

with parents, even after controlling for parents' SES and the parent-child relationship. Book Start, an intervention program in which Dutch parents were supplied with a new book and instructional material soon after their children were born, was only effective at boosting the language development of temperamentally reactive toddlers, and not for children with less difficult temperaments (van den Berg & Bus, 2014). Finally, although Landry et al. (2012) did not report a measure of child temperament per se, they found that the benefits of the PALS intervention for book-reading quality were stronger for mothers of very low birthweight (VLBW) infants. Mothers of infants with VLBW who were in the intervention condition were more likely to provide general verbal support and less likely to simply read the text. Infants with VLBW are more vulnerable and also more likely to have difficult temperaments. Together with van den Berg and Bus's (2014) findings, it is encouraging that with even minimal support, parents of children with difficult temperaments try even harder to create a high-quality book-reading experience.

### *Birth order/family size*

In contrast, new research identifies the expected negative associations between birth order and family size and high-quality book-reading. For instance, Raikes et al. (2006) found that consistent, daily book-reading from ages 1 to 3 years was more likely for firstborn children than for laterborns. Farrant and Zubrick (2012) also found shorter durations of book reading (between 9 and 34 months) as a function of the number of siblings for the target child. The more children in the family, the less likely it is that young children will experience frequent and lengthy book-reading sessions.

## ***Book factors***

### *Repeated readings*

New research has produced clear findings on the benefits of repeated readings of the same book for children's word learning. For instance, in an experimental demonstration, 3-year-old children learned and retained more new words from hearing three books, each read three times, than from hearing the same words in nine different books (Horst et al., 2011; cf. McLeod & McDade, 2011).

Fletcher and Finch's (2015) study with low-income mothers reading three new books, four times each, is also relevant here. Although mothers' reading strategies were very stable across the repeated readings, children became more responsive over time, suggesting that they were better able to respond to mothers' questions and comments as they became more familiar with the book. Even at this young age, toddlers were more responsive to mothers' positive feedback and questions than to comments (mostly labels) and reading of the text.

### *Type/genre*

New studies show that book type can affect the quality of the interactions, for better or worse. For instance, expository books can elicit more high-level extratextual talk than a narrative picturebook from both mothers and fathers (Price, van Kleeck, & Huberty, 2009; although cf. Robertson & Reese, 2017). In contrast, e-books can disrupt high-quality interactions if technological features distract the dyad from a discussion of the content of the story (see Reich, Yau, & Warschauer, 2016, for a review; cf. Chapter 25, this volume). Finally, in a comparison of rhyming versus prose picturebooks (both narrative), we found that parents focused more on sound talk

in the rhyming book, and used a higher proportion of inferences in the prose book, although there were no differences in the amount of extratextual talk across the two books (Riordan et al., 2018). Thus, books from different genres and formats may elicit differing amounts and kinds of interaction.

### *Complexity*

Related to book type, new research is showing clearly that less complex text (and no text) can support high-quality interactions. For instance, one study in Colombian preschools compared the same teachers reading wordless picturebooks and well-matched texted picturebooks (Chaparro-Moreno, Reali, & Maldonado-Carreño, 2017). Teachers were more interactive and used greater lexical diversity when reading the wordless picturebooks than the texted picturebooks. In a related vein, when comparing two well-matched picturebooks that varied on the amount of text, mothers used similar amounts of extratextual talk and high-level talk across the two books (Muhinyi & Hesketh, 2017). Because high-text books take longer to read, the authors recommended that low-text books could produce the same amount and quality of talk in less time. In the only study to date to conduct a grammatical analysis of extratextual talk, Noble et al. (2017) found that children's books with simple texts elicit syntactically more complex extratextual talk from parents compared to grammatically complex texts. Simpler books may be better for promoting high-quality extratextual talk.

### *Frequency*

In Fletcher and Reese (2005), we noted that book-reading studies largely considered frequency and quality issues separately, and this trend has continued in the latest research. Very few studies report the correlations between quantity and quality even when they have collected both variables (e.g., Kucirkova et al., 2018). Perhaps this absence is due to there being no significant association between quantity and quality. For instance, Malin et al. (2014, Table 3) found no significant correlations between the reported frequency and observed quality of book-reading for either mothers or fathers. Thus, we still do not know if increasing the quantity of book-reading – for example, in the Book Start intervention – necessarily increases the quality of book-reading.

### *Familiarity*

Fletcher and Finch (2015) tracked low-income parent-toddler interactions as they became familiar with three new books over repeated readings, an improvement on previous designs that analyzed different favorite books across dyads (e.g., Haden et al., 1996). Mothers' reading style differed by book, but was largely stable across multiple readings over time. However, as pointed out above, children became more responsive over the repeated readings, suggesting that familiarity enhanced their verbal contributions to the interactions.

## Unanswered questions about book-reading and children's language development

As intimated earlier, we need to know more about how book-reading promotes children's syntax and phonological awareness. It seems likely that the type of book will be critical in creating these benefits. Rhyming books, for instance, may help children's phonological awareness directly,

and they also elicit sound talk from parents, creating a double-whammy for children's sound awareness. I also advocate for more research on parental stress/depression and book-reading quantity and quality. Could depressed parents be taught to engage in islands of high-quality interaction via book-reading?

We also need more research on parental beliefs about the value of reading and how best to read to children, especially as these beliefs interact with cultural values about child-rearing and the value of direct interaction with children versus indirect interaction. The current focus on increasing book-reading quantity and quality among parents of low-income children as a monolithic entity is unlikely to be successful if we do not take into account language and reading barriers parents experience that limit their book-reading interactions (Justice, Logan, & Damschroder, 2015). We need to consider carefully cultural beliefs about ways to interact with children that do not line up with a highly interactive style of reading. For instance, in some Pacific cultures, older siblings are more often the ones directly interacting with young children because it is considered less appropriate for parents to put themselves at the child's level (Ochs, 1982). Thus, older siblings or perhaps grandparents would be a better target than parents for book-reading interventions in some cultures. Many more Pacific Island, Asian, and Māori children in New Zealand live in extended family settings compared to European children (Morton et al., 2017), so there are other adults besides parents in the home to serve as potential book-reading partners. On that note, we know next to nothing about the quantity and quality of grandparent-grandchild book-reading interactions. Some of these interactions will be direct, but others are now indirect via video calling. Do these virtual book-reading interactions make a difference for children's language skills? Or are they predominantly important for strengthening the bond between grandparent and grandchild?

Continuing with the cultural theme, book-reading may not be the ideal conversational context in some cultures that have more of a focus on oral conversations (e.g., some African-American, Pacific, and Māori cultures). Other high-quality language interactions between adults and children, such as reminiscing or oral storytelling, may be a complementary or even better target for intervention in these cultures. For instance, African-American mothers used more decontextualized speech in an oral storytelling interaction than in a book-reading interaction with their children (Curenton et al., 2008). Although naturalistic sampling shows that parents talk more during reading times than during non-reading times (Gilkerson, Richards, & Topping, 2017), the differences in quality talk between book-reading and structured play sessions are sometimes slight. For instance, low-income fathers asked more questions and used more word types when reading books, but they used longer MLUs when engaging in toy play (Salo, Rowe, Leech, & Cabrera, 2016). Moreover, Sosa (2016) found few differences in speech quality when middle-class parents read books with their toddlers versus played with a traditional toy (e.g., tea set). In a similar vein, Weizman and Snow (2001) demonstrated that low-income mothers spontaneously used more rare words during mealtimes and playtimes than during book-reading sessions; only mothers' rare words during mealtime and playtime, not book-reading, predicted children's vocabularies two years later. Finally, Pollard-Durodola et al. (2017) found that the book-reading component of a vocabulary intervention was not essential or even especially beneficial for children to learn new words in a preschool setting; they learned just as many new words from well-matched, highly interactive play and conversation sessions that did not include book-reading. Ultimately, we need to know whether book-reading is a special form of interaction for children's language, or whether there are other conversations that can create similar or even larger effects.

New research is emerging on the visual/aesthetic features of picturebooks, such as artistic conventions and the quality of the illustrations (Sparks, 2017). Picturebooks are, after all,

primarily a visual art form (Kiefer, 2011). Do highly aesthetic picturebooks promote higher quality interactions among parents and teachers, or can high-quality interactions also spring from books lower in artistic quality? Can e-books rival or surpass print picturebooks in aesthetic quality, without distracting readers and children from the content of the story? This information is essential when designing book-reading interventions for low-income families who will not be able to afford the latest high-quality picturebooks after the intervention has ended. Can they create the same high-quality interactions with cheaper books purchased at the grocery store or at secondhand shops, or with e-versions?

Last but not least, we need more research on what makes book-reading interactions enjoyable for both parents and children. Robertson and Reese (2017) found that children (but not their parents) reportedly enjoyed an expository book more than they enjoyed a narrative book. If children are more engaged in the reading, parents may read longer or more often (Farrant & Zubrick, 2012), and the resulting interactions are likely to be of higher quality.

## Conclusions

It is undoubtedly clear from this review that high-quality book-reading interactions – defined as responsive conversations containing rich information about vocabulary and narrative structure that encourage children's engagement – are the ones that advance children's language development. Therefore, our focus should be on figuring out the factors that foster high-quality interactions among children and their book-reading partners (parents, teachers, grandparents, aunts and uncles, older siblings, community workers) from diverse cultures and language backgrounds, and with a wide range of picturebooks. Given the importance of language skills for school readiness (e.g., Forget-Dubois et al., 2009), and the critical role of school readiness for opportunities in contemporary societies (Britto, 2012), every child in the world should have access to the worlds within the pages of picturebooks.

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# 25

# USING DIGITAL MEDIA TO SUPPORT LANGUAGE LEARNING IN EARLY CHILDHOOD

*Gabrielle Strouse*

The digital technologies that now feature prominently in young children's daily lives are quite different from prior decades. Touchscreen technology has made digital devices more easily controllable by young children than computers of the past (Heller, Sturner, Funk, & Feezor, 1993; Mourlam, Strouse, & Newland, 2018; Scaife & Bond, 1991), greatly changing access to digital media content for the very young. Previously, parents may have concentrated on print rather than digital media as an avenue for improving literacy skills. A large body of research has focused on the role of print media in literacy development, establishing shared reading and access to children's books as important components of a high-quality early literacy environment at both home and school (e.g., Bus, Van Ijzendoorn, & Pellegrini, 1995; Mol, Bus, De Jong, & Smeets, 2008). For example, parent reports of shared reading at home during kindergarten are associated with children's vocabulary in kindergarten and the beginning of grade 1 (ages 5–6 years; Sénéchal & LeFevre, 2014). Shared reading at school in the preschool years (ages 3–4 years) is associated with higher vocabulary scores, and extratextual conversations during reading are predictive of language growth in preschool and of vocabulary skills at the end of kindergarten (ages 5–6 years; Zucker, Cabell, Justice, Pentimonti, & Kaderavek, 2013).

The vast research on the effectiveness of print media experiences as a component of healthy development has led to both financial and policy support for children's book programs from the American Academy of Pediatrics (High et al., 2014). However, digital devices have brought new platforms for learning into homes and early childhood classrooms that have not yet received the same policy support. Instead of encouraging use, parents are told to greatly limit children's access to digital screens, especially at the youngest ages (Hill et al., 2016). What do we know about how well these devices function as learning tools to promote language and literacy development in children prior to school entry? In this chapter I will review the literature on language learning from traditional digital devices (televisions and computers), discuss what makes learning language from these devices similar to and different from learning with newer digital devices, and present the growing evidence for and against using newer devices as literacy tools for our youngest learners. I have chosen to focus this review on direct acquisition of language, i.e., word learning and vocabulary outcomes.

## Language learning from video

Studies from as early as the 1970s, when *Sesame Street* was just beginning, showed that preschool-aged children (3–4 years) learned a variety of information, including the alphabet, numbers, and receptive vocabulary, from *Sesame Street* (Ball & Bogatz, 1970; Bogatz & Ball, 1971; Diaz-Guerrero & Holtzman, 1974; Rice, Huston, Truglio, & Wright, 1990; Zill, 2001). Longitudinal studies indicated that children who watched *Sesame Street* maintained academic gains through early elementary school (Wright & Huston, 1995) as well as through adolescence (Huston, Anderson, Wright, Linebarger, & Schmitt, 2001). As more children's shows emerged on the market, researchers showed that preschoolers were learning from these too: for example, there were cognitive gains from *Blue's Clues* (Anderson et al., 2000) and cognitive, social, and vocabulary gains from *Barney and Friends* (Singer & Singer, 1998). This body of work demonstrated that children's television could be effectively educational. When the American Academy of Pediatrics' media recommendations came out in 1999, the authoring committee raised concerns about media's link with obesity and emphasized children's need for person-to-person interaction. These concerns appear to have been based on displacement – the idea that screen time might replace activities that burn more calories, or time children spent interacting with social partners – rather than a concern that television was not educational. In fact, pediatricians were specifically encouraged to "advocate for increasing educational and prosocial programming and messages for children and youth" (American Academy of Pediatrics, 1999, p. 342).

After the initial release of the AAP guidelines, some researchers' attention shifted to younger children, as two parallel trends emerged. First, allegedly "educational" programming targeted at infants and toddlers grew in popularity. *Baby Einstein*, *Baby Genius*, *Your Baby Can Read* and other products were marketed to parents of infants as educational. Researchers reacted with a variety of publications showing that videos marketed to teach infants vocabulary had little or no impact on vocabulary growth (DeLoache et al., 2010; Robb, Richert, & Wartella, 2009; Vandewater, 2011), and videos designed to teach infants to read resulted in no indication of children acquiring any of a variety of early literacy skills (Neuman, Kaefer, Pinkham, & Strouse, 2014). One interesting finding across these studies was that when children were assessed directly, no vocabulary growth was apparent, but when parents were asked to report what children learned from the videos, parents reported growth (DeLoache et al., 2010; Neuman et al., 2014; Vandewater, 2011). This set up the dangerous possibility that infants were not learning language from these products, but that parents believed they were. Along with these experimental results, several correlational studies found negative or non-existent associations between video exposure prior to school entry and vocabulary growth (Blankson, O'Brien, Leerkes, Calkins, & Marcovitch, 2015; Hudon, Fennell, & Hoftyzer, 2013; Patterson, 2002; Schmidt, Rich, Rifas-Shiman, Oken, & Taveras, 2009; Taylor, Monaghan, & Westermann, 2017; Tomopoulos, Dreyer, & Berkule, 2010; Zimmerman, Christakis, & Meltzoff, 2007; but see also Linebarger & Walker, 2005).

Second, researchers working on memory (Barr & Hayne, 1999; Hayne, Herbert, & Simcock, 2003) and children's understanding of symbolic representations (e.g., photographs and videos; Schmitt & Anderson, 2002; Suddendorf, 2003; Troseth & DeLoache, 1998) found that infants and toddlers did not learn as well from videos as they did when information was presented directly by people. An influential study comparing infants' retention of the ability to distinguish Mandarin speech sounds after exposure to an in-person, video-recorded, or audio-recorded Mandarin speaker showed that 9-month-olds only retained these sounds when exposed to a live speaker (Kuhl, Tsao, & Liu, 2003). A 2005 review (Anderson & Pempek, 2005) termed the domain-general difference in learning from video and face-to-face experiences the *video deficit*. Later research has confirmed the effect is present in video word learning studies (Krcmar,

Grela, & Lin, 2007; Krcmar, 2010; Hakuno, Omori, Yamamoto, & Minagawa, 2017; Roseberry, Hirsh-Pasek, Parish-Morris, & Golinkoff, 2009). Thus, the video deficit potentially impacts the effectiveness of video in supporting literacy development in infants and toddlers, and offers a black-box explanation for why baby videos designed to teach language did not appear to be effective. But what causes the video deficit? And in what circumstances does it apply to learning from other screen media?

## *Video deficit*

A few competing hypotheses have been proposed to explain young children's relative struggle to learn from video (for an in-depth review, see Barr, 2010; Troseth, 2010). According to one, the mismatch between learning and application contexts may play a role in children's struggle to apply information from one source (e.g., a screen) to another context (e.g., the real world). One part of this mismatch, perceptual impoverishment, posits that young children struggle with the visual mismatch between objects presented on screen and those presented in real life due to video screens' resolution, size, and 2-dimensional nature (Barr & Hayne, 1999). Perceptual mismatch could result in children failing to access memory of a video when they experience a matching real-world object or situation. A more general contextual mismatch hypothesis includes mismatches not just in visual representations but also in other aspects of the context of the learning and application situations. This theory would predict that information learned from *any* 2-dimensional source may not be easily recalled and used in 3-dimensional contexts, and vice versa. Consequently, we would expect contextual mismatch to affect learning not only from television screens, but also from tablets, smartphones, and other devices that provide 2-dimensional visual output. This pattern has indeed been observed with touchscreens in studies in which children were asked to repeat a behavior they learned on a touchscreen with real objects (and vice versa; Moser, Zimmerman, Dickerson, Grenell, Barr, & Gerhardstein, 2015; Zack, Barr, Gerhardstein, Dickerson, & Meltzoff, 2009).

Other theories about the video deficit focus on conceptual explanations. According to these theories, children may not transfer information from screens to the real world because they do not realize the source is meant to represent reality (Troseth, 2003, 2010) or because they have not had any prior meaningful social experiences with the actors (Krcmar, 2010). After watching a large number of irrelevant and unrealistic video portrayals, or even realistic videos of faraway places and things, children may view the people and objects on video as separate from real life rather than a recording of real events. According to some conceptual theories, greater experience with more realistic video may allow children to learn to recognize that some video content is intended to represent reality and subsequently fare better at learning and transfer tasks (Troseth, 2003; Troseth, Casey, Lawver, Walker, & Cole, 2007). Having a concept that video is not intended to represent reality may result in a lack of language learning. For example, it may result in an intentional disregard for the information as irrelevant, similar to how 4-year-old Canadians selectively did not learn the names of toys intended for children in Japan but did learn the names of toys for children "around here" (Henderson, Sabbagh, & Woodward, 2013). It may also result in "quarantining" of video information, or failure to believe that information presented in a particular context, like a fantastical story, applies to the real world (Richert & Smith, 2011; Richert & Schlesinger, 2017). For example, American preschoolers who watched clips from *Dora the Explorer* and *Ni Hao, Kai Lan* featuring foreign words were more likely to learn the words if they believed the words were real and not made up for the show (Mares & Sivakumar, 2014). Using this perspective, one might predict that children's experience with digital devices would predict their subsequent learning from them. Some children might have particular difficulty learning

from newer digital devices like tablets and smartphones, as these provide many apps and functions that do not directly represent the real world in the same way that children experience it. Separating which information is relevant, realistic, and meant to be learned from unrealistic and fantastical information may be difficult for children with these types of experiences.

Finally, a line of research has focused on the importance of social cues for learning. Kuhl and colleagues suggested that infants may not learn language from video because in-person social cues are critical to attract infant attention and motivation for learning (Kuhl et al., 2003) and because social interaction provides enriched language information (Kuhl, 2007). Many social cues are necessarily missing from traditional video, as on-screen actors cannot share joint attention with infants, react to their gaze, or provide orienting cues when infants' attention wanes. New media provides an especially complicated landscape for making predictions from this perspective, as new technologies like FaceTime allow for responsive human partners to communicate through screens, and touchscreens allow infants to interact with screens in ways that can somewhat mimic social interactions. Here we must dig deeper into the video literature to determine what aspects of social interaction are most important for word learning in media contexts, and which have been successfully mimicked in video environments, to help make predictions about learning from other devices.

## *Language learning from social cues*

The presence of an on-screen person who provides social cues may support language learning from videos. Krcmar and colleagues (2007) found that 15- to 24-month-olds learned a new word more often from a live speaker who provided joint reference (picking up an object and looking at it while labeling it) than they did from a clip of a *Teletubbies* program in which a voiceover provided a new label for an on-screen object (no speaker appeared). Two comparison conditions provided additional information about cues that supported performance: 1. when the live speaker did not provide joint reference (children's attention was distracted by a noisy toy), word learning was lower than when the live speaker provided joint reference, and 2. when a prerecorded on-screen actor provided the label in a format similar to the live speakers, performance was higher than in the *Teletubbies* (no speaker) condition. This study suggests that a speaker who provides referential cues to a labeled object is supportive of learning whether that display occurs live or on video; however, when children are distracted from this display by a noisy toy or when the label is provided with no referential cues, learning is lower. We might infer that the presence of an on-screen speaker who provides social and referential cues is supportive of young children's language learning from video and may explain some differences in learning between live and video situations.

However, several research studies have indicated that young children can also learn words from video in the absence of a video labeler. Krcmar (2014), studying 1.5-year-olds, and Scofield, Williams, and Behrend (2007), studying 2-year-olds, found that children successfully learned words from a video that provided a simple voiceover, with no speaker present on screen. In a follow-up, to Scofield and colleagues' (2007) study, 2-year-olds also transferred the labels learned from voiceovers to real, 3-dimensional versions of the objects (Allen & Scofield, 2010). While these results suggest a contrast to Krcmar and colleagues (2007), some learning from video without an on-screen speaker is consistent with Krcmar and colleagues' (2007) study, in which learning occurred in all of their live and video conditions, just not at equivalent rates. In these studies (Allen & Scofield, 2010; Krcmar, 2014; Scofield et al., 2007) the target object was shown by itself on the screen during labeling, so children did not have to disambiguate to which on-screen object the label referred. In these cases, on-screen speaker support may be less important

to young children's learning. In addition, older 3- to 5-year-old children can succeed in learning words from computer touch screens and videos with an on-screen speaker, including in cases in which disambiguation is necessary (Rice and Woodsmall, 1988; Wilkinson & McIlvane, 1997; Wilkinson & Mazzitelli, 2003).

Two- and 3-year-olds' successful word learning from video in some studies has been used as evidence that the video deficit effect on language learning may be "overcome" by age 3 (Krcmar & Cingel, 2017, p. 8). A deficit has been found in studies with children as old as 30 months (Roseberry, Hirsh-Pasek, & Golinkoff, 2014; Troseth, Strouse, Verdine, & Saylor, 2018), but direct live/video comparisons of word learning at older ages have not been done. As children develop, they may be more able to understand subtle cues to reference (Ahktar & Tomasello, 2000), making them better at using on-screen cues to support word learning. However, the relative inefficiency of word learning from screen media versus live speakers during the preschool years (ages 3–5 years) is still in need of exploration. Even in cases where children can learn in the absence of on-screen speakers, there presence may still be supportive. Kalashnikova, Mattock, and Monaghan (2016) showed that while 4-year-olds could learn words from video in the absence of on-screen speakers, having the speakers on screen was helpful even for children at this age. They found that 4-year-olds who learned the label for one object from an on-screen speaker then correctly applied a new label to a new object (mutual exclusivity) and were able to keep track of on-screen speakers who used different words for the same objects. However, when speakers were not present on screen, and thus visual cues to reference were absent, even 4-year-olds struggled to learn words for an object given by different speakers.

The on-screen presence of a speaker may be important because of the specific referential cues that the speaker is able to provide. Beginning around 9–12 months of age, infants are sensitive to adults' reference when labeling objects and use cues such as gaze when learning words (Ahktar & Tomasello, 2000; Baldwin, 1993). Researchers have corroborated the supportive nature of on-screen speakers' referential cues for word learning from video for children in their second year of life by comparing videos with and without particular cues. For example, de Villiers Rader and Zukow-Goldring (2010) showed that on-screen gestures directed word learning: when the speaker lifted and rotated the target object during labeling (as opposed to before or after labeling), infants 9 to 14 months old directed their attention to the object as the label was said aloud, and this was associated with learning. Houston-Price, Plunkett, and Duffy (2006) showed that 15-month-olds were sensitive to the direction an on-screen face was oriented and could use that to help them assign a label heard on video to the appropriate depiction of an object. Finally, Briganti and Cohen (2011) found that 18-month-olds learned a word from a video speaker who pointed and nodded toward the correct referent (although 14-month-olds did not). Thus, the relatively simple social referential cues of holding up objects during labeling, face orientation, pointing, and nodding supported word learning from video for children in their second year of life.

Social referential cues may also be important to video word learning for somewhat older children. Roseberry and colleagues (2014) found that 24- to 30-month-olds' attention to an on-screen speakers' eyes was predictive of individual differences in verb learning from the speaker. In addition, O'Doherty and colleagues (2011) found that 30-month-olds were more likely to learn words when the on-screen speaker was addressing another on-screen person – showing her the labeled object, displaying joint attention on the object during labeling, and handing over the toy for the confederate to look at – than when she was addressing the camera directly. In other words, when children saw or overheard a situation with a variety of intact social cues, they were more likely to learn, compared to situations with no visible joint reference or exchange of the toy (for further discussion, see Chapter 22, this volume). However, a more recent study using

a very similar paradigm, but video production values meant to match typical children's television programming, found the reverse effect (Krcmar & Cingel, 2017). These contrasting studies provide evidence that more research is needed to understand the interaction of on-screen social cues, context, and experience in promoting word learning for children in this age range.

Other referential cues not provided by on-screen people may also support word learning. In addition to the on-screen face-orientation cue, Houston-Price and colleagues (2006) found that 15-month-olds could use object movement as a cue to word reference. However, when object movement was pitted against gaze from an on-screen face, infants prioritized the gaze in assigning the new label. This suggests that while infants rely on social cues from individuals on screen to help them learn words, in the absence of these cues non-social cues can scaffold learning. Jesse and Johnson (2016) also found that when an on-screen image was animated, and this animation matched the auditory labeling, that 24-month-olds were more likely to learn the word than when the animation and auditory labeling were mismatched. Thus, on-screen movement synchronized with labeling can help children figure out what a new word is referring to in the absence of informative social cues to reference.

Thus far, I have argued that young children learn less efficiently from videos without on-screen speakers, or with speakers who fail to provide meaningful gaze or referential cues, than from videos including these cues. While it is not universal that infants and toddlers always learn words from on-screen speakers using referential cues like gazing at, pointing at, and holding up objects, it generally appears that the presence of these cues is supportive. In addition, non-social cues like movement and animation can direct young viewers to the referent of word labels in the absence of an on-screen speaker. Based on the research with video, we would expect that new media that incorporates both social and non-social cues in an integrated manner should best support children's learning. In addition to movement and sound cues used in traditional television, hotspots (on-screen areas that can be activated to trigger a response) included in touchscreen games may act to draw children's focus to on-screen objects to which they should attend. However, as indicated by the control conditions in the studies described above (de Villiers Rader & Zukow-Goldring, 2010; Jesse & Johnson, 2016), it may be important for these hotspots to be aligned synchronously with labeling in order for them to act as effective supports for learning.

## *Language learning with co-viewers*

In addition to on-screen cues, social cues and scaffolds provided by in-person co-viewers in the child's environment have supported word learning from video in a variety of studies. In one lab-based study, 2-year-olds were more likely to learn words when a parent reminded the child that the on-screen objects were the same as the 3-dimensional objects in the room, as opposed to when the parent did not remind the child (Strouse & Troseth, 2014). In another lab-based study, 3-year-olds displayed more verb learning when they watched a person provide a new verb label both on screen and in person than when they watched the video alone (Roseberry et al., 2009). Researchers have also found that co-viewing parents support learning from commercial video products, including learning signs from a video for infants (Dayanim & Namy, 2015) and learning words from video storybooks (Strouse, O'Doherty, & Troseth, 2013). The influence of supportive co-viewers also carries into later grades, as first and second grade Chinese students ($M$ = 7 years of age) learned more English words from cartoons when they were accompanied by an in-person instructive warm-up task, in which they saw, heard, and promoted the words (Sun & Dong, 2004). Thus, even though language learning may not be optimal in digital environments, co-viewers may provide extra cues and scaffolds that support learning.

I have previously laid out three mechanisms through which co-viewers may support children's learning from video (Strouse et al., 2013). First, co-viewers may direct children's attention to programs or aspects of programs that are important for learning. Infants follow their parents' gaze to the television, often looking to the screen immediately after their parent looks (Demers, Hanson, Kirkorian, Pempek, & Anderson, 2013), and parents attending to the screen may model that it should be attended to (Strouse, Troseth, O'Doherty, & Saylor, 2018). Social cues may act as attention directors in these cases, but we might expect that on-screen formal features such as animation, movement, and sound would also direct attention, perhaps in similar ways. New media directs attention in new ways, such as responses that occur when a child touches the screen or speaks aloud, which may have additional potential for supporting children's learning. Second, co-viewers may provide cognitive supports for learning by discussing content with children. These discussions could involve memory retrieval and rehearsal ("What is the place the bear slept called?") or provide additional exemplars of new concepts and words ("The bear is sleeping in a den. Dens are also called lairs."). In one study the *content* of the scaffolds that parents provided during video watching was important to children's vocabulary growth and comprehension (Strouse et al., 2013), emphasizing that supportive co-viewing involves more than just directing the child's attention to things on screen. There may also be ways to build cognitive supports into new media by adding questions for children to respond to or providing simple games or animations with additional exemplars of new information. Finally, the third way that co-viewers may support young children's learning is through social feedback, which involves contingently responding to both the child and the screen ("You're right, the bear is crying.") and contextualizing new information by relating it to the child ("How do you feel when you are crying? Do you think the bear feels sad too?"). This is one area that new media may not be good at mimicking, as this type of support is very child-specific and requires knowledge of children's skills, learning preferences, and life experiences.

While media can include scaffolds that use similar mechanisms to those used by co-viewers, co-viewer support seems to have a greater effect on children's learning from and enjoyment of media and combining co-viewer support and media scaffolding probably has even greater benefit. Two recent studies showed that when new labels were provided on video chat, a new platform in which on-screen people can respond contingently to children, children learned more words when co-viewing parents provided additional support (Myers, Crawford, Murphy, Aka-Ezoua, & Felix, 2018; Strouse et al., 2018). In the next section I discuss what we know about how children learn from this new type of video.

## *Language learning from video chat*

Direct communication between two people via video chat offers children the opportunity to interact in real time with an on-screen partner. Platforms like Skype and FaceTime have made video chat accessible to many young children on a very regular basis. Two early studies were designed to test whether an on-screen actress who could share focus on the same objects as the child (by viewing them over a closed-circuit camera setup), refer to the child's immediate surroundings (which she saw on screen), and respond to the child's bids for conversation would support children's learning from video (Nielsen, Simcock, & Jenkins, 2008; Troseth, Saylor, & Archer, 2006). Children who participated in the closed-circuit video conditions of the studies were more likely to use information from the video to solve a real-world task than those who viewed a recorded video of another child's session. These studies showed that the video chat interaction provided support for children's use of the information presented on screen beyond that provided by a recording of the same social cues and references. A recent study using a word

learning task indicated that video chat also supported word learning from video for 22- to 25-month-olds (Myers, LeWitt, Gallo, & Maselli, 2017), although 12- to 21-month-olds did not seem to benefit from video chat.

These studies suggest a promising phenomenon –video incorporating social contingencies similar to real life leads to learning similar to live presentations. However, these early studies included a couple of significant confounds which are worth addressing. First, in the two earliest studies (Nielsen et al., 2008; Troseth et al., 2006), researchers provided children in the closed-circuit conditions with an extensive warm-up experience to teach children about the live-feed setup, which included parents being addressed by the on-screen actress and answering questions when children were hesitant to do so. Thus, children in the closed-circuit conditions had more interaction with their co-viewing parent than children in the recorded versions, confounding on-screen video chat contingency and in-person co-viewer support. In the more recent study, direct talk between the parent and actress was eliminated, but parents still responded to the actress by retrieving toys that she requested (Myers et al., 2017). Although a co-viewing parent is likely often present and active in toddlers' video chat interactions during daily life (e.g., video chatting with grandparents), this confound makes it unclear whether contingency *in the video* or contingency *in the child's environment* supported learning in these studies.

Even when this confound has been addressed, a second important confound has arisen. Roseberry, Hirsh-Pasek, and Golinkoff (2014) had 24- to 30-month-old children watch an on-screen actress label an action with a novel verb and then tested their verb learning. Children participated on their own (parents wore opaque glasses and did not participate), eliminating the parent co-viewer confound, and children in the Skype condition learned more verbs than those in the comparison condition, who watched a recording made from another child's Skype session. However, children in the comparison condition in this study (Roseberry et al., 2014) and the other studies (Nielsen et al., 2008; Roseberry et al., 2014; Troseth et al., 2006) viewed recordings of other children's actions which provided explicit misinformation (using another child's name and details). These inaccurate details may have highlighted the video's lack of contingency and relevance to the viewing child (they heard praise based on another child's actions and using another child's name, not their own). As a result, the recorded videos used in the comparison conditions may have been more difficult for children to learn from than typical children's videos, in which the child is either not addressed, or is addressed generically. A recent study (using video but not video chat) included a condition in which misinformation provided after a pause was associated with lower levels of learning: Nussenbaum and Amso (2016) found that 3- to 5-year-olds were more likely to learn words from a video speaker when the speaker asked a question to the camera, paused, and waited for a response than when the speaker *also* gave a potentially inaccurate reply after the pause ("That's right! You're speaking Swahili just like me!"). The authors indicated that the final comment appeared to draw children's visual attention away from the labeled object. It is possible that the misinformation given in the control conditions of the previously described studies (Nielsen et al., 2008; Roseberry et al., 2014; Troseth et al., 2006) is one mechanism for the differential success of the video chat and prerecorded conditions.

Three more recent studies have addressed this concern by using a generic ask-and-wait style comparison condition (Myers et al., 2018; Strouse et al., 2018; Troseth et al., 2018). In these studies, 2-year-olds participated in a video chat in which the actress directly addressing them, then paused and waited for a response, similar to many popular children's television characters (e.g., *Dora*). In all three studies, 2-year-olds failed to learn new words from the video chat alone, although in two of the studies 2-year-olds learned from video chat in the presence of a participatory co-viewer who modeled responsiveness to the screen (Myers et al., 2018; Strouse

et al., 2018). This suggests that the responsiveness of the on-screen actress by itself may not have been driving the effects in prior studies, but rather that misinformation may have artificially lowered the success of children in the prerecorded conditions. Simple contingences provided through media may not be as powerful as co-viewers in supporting children's learning. Additional research is needed to determine the role of video chat in other learning situations and over repeated exposure.

### *Summary: language learning from video*

Infants and toddlers can learn words and other literacy skills from video, but learning in many cases is not as efficient as learning from in-person social partners. Several theories of the video deficit suggest implications for learning from other digital platforms. First, contextual mismatch predicts that children may struggle to apply information from any learning context that is substantially different from the application context, and predicts inefficiencies in application of information from any type of digital media to the real world. Second, conceptual difficulties with transfer of information from video to the real world may stem from children viewing the actors and objects on video as irrelevant to reality. Children's differing experiences with media as realistic or unrealistic may influence their insight into which experiences are to be learned and applied versus those that are to be quarantined inside a particular media product or platform. Finally, social cues are an important part of early language learning. Both on-screen social partners who provide cues to reference and non-social cues that provide reference through contingent movement can provide support for video word learning. When social and non-social cues are both available on screen, children appear to prioritize social cues for learning. Conversely, asynchronous cues and those that provide misinformation may detract from learning. Thus, the type and application of referential cues could be an important component of supporting learning from other digital media. Given the limitations of the studies so far, it is difficult to know whether the contingency available in video chat provides significant advantage over a prerecorded on-screen social partner. Finally, regardless of what is available on screen, co-viewers appear to provide additional support for learning.

## Language learning from touchscreen devices

The video literature gives us important lessons about how children learn from screens with which they have limited control and interaction. Touchscreens present many of the same challenges as other digital media – contextual mismatch between learning and application, the need for conceptual understanding of what information is relevant and what should be transferred, and a lack of built-in social cues. As a result, we might expect that the same features identified from video research – for example, social and non-social on-screen cues, and co-viewer support – to predict learning from touchscreen devices.

Research with touchscreens will continue to identify supportive features that apply generally to all screen-based contexts. For example, Axelsson and Horst (2014; see also Chapter 11, this volume) identified contextual repetition as one on-screen cue that can support language learning in the absence of a speaker. Three-year-olds who saw consistent, predictable distracters alongside novel labeled referents on a touchscreen displayed more learning. This is just one example of how touchscreen studies may identify supportive features that could be applied to learning from other media (and non-media) situations.

However, touchscreens also provide unique opportunities for learning: they make contingent, adaptive interaction with a device highly accessible for young children, possibly bringing

with it the ability for the device to mimic social cues and other scaffolds that support learning in ways that other media cannot. Touchscreens also offer new affordances such as giving children the ability to direct their own learning and to physically interact with screens in new ways (e.g., touch the animal you want to learn about). However, these same affordances that hold promise for supporting learning may also distract children, highlight the device's game-like nature, and provide false impressions to adults that they no longer need to provide support through co-use. These affordances may also interact with aspects of the child or the child's prior experience such that they may be differentially supportive for different children in varied contexts.

There is evidence that learning from touchscreens, like learning from video, can be challenging for young children. Strouse and Ganea (2017b) showed that 17- to 23-month-olds were less likely to generalize or transfer new object labels when an adult labeled pictures on a touchscreen than when she labeled the same objects in a printed book. In-person social cues delivered by the adult were intact and consistent across both conditions, but there was still a difference in transfer and generalization between the two 2-dimensional formats. Thus, social cues and contextual mismatch were unlikely explanations for differences in learning. However, there was evidence that toddlers' prior experience with screens predicted their success in the tablet condition. Those who primarily used tablets to watch videos were less likely to learn the label than those who typically experienced a variety of activities on tablets. The authors argued that varied experiences with tablets may have helped children learn that sometimes information on tablets is relevant to real life and should be transferred. Kirkorian and Choi (2016) reported a similar benefit of experience for toddlers participating in an object-retrieval task.

In addition to the role of prior experience in predicting children's learning and transfer from touchscreens, Russo-Johnson, Troseth, Duncan, and Mesghina (2017) suggested that it may be important to pay attention to other individual or developmental differences in determining how to best harness touchscreens for word learning. In their study, 2- to 4-year-olds heard a voiceover label objects on a tablet screen. Children either watched the objects move across the screen, tapped to initiate their movement, or dragged the objects across the screen. To test for word learning, children were asked to identify the labeled object both on screen and from a pair of real 3-dimensional objects. Older girls benefited from dragging the objects and boys benefited from watching. The authors noted that in another task boys and children with low self-regulation tended to tap inappropriately (high amounts of tapping during instructions and labeling events). They suggested that perhaps tapping is not always thoughtful, and might distract children with low inhibitory control from important content. On the other hand, dragging may require more motor control and may frustrate or distract younger children. Ideally, individual motor and self-regulation skills should be taken into account to optimize apps for learning.

Kirkorian, Choi, and Pempek (2016) also highlighted developmental differences in learning from touchscreens. They showed 24- to 36-month-olds a video on a tablet in which an on-screen actress removed objects from boxes and labeled one of them with a new word. Some children watched the video play on without pausing, like a traditional video. Two other groups of children experienced a video that paused and required a touch to continue playing. One of those groups could touch anywhere on the screen, and the other group needed to tap specifically on a box in which the to-be-labeled object was hidden to resume the video playback. Testing occurred with real 3-dimensional versions of the objects. Younger children in the age range learned best when they tapped the specific box to hear the label. Older children were most successful when they watched the video play back without tapping the screen. The authors suggested that for younger children, perhaps tapping the box directed attention to the relevant information to be learned, similar to how animation/movement has been used to direct children to appropriate referents in video studies. On the other hand, older children may have

learned the label, but "bound" the new label to the tablet, not transferring it to the real-world context at test.

These three studies indicate that what children bring with them to the word learning situation plays a role in how they learn from touchscreens. These studies also highlight affordances that make learning from touchscreens different from learning from video, i.e., through specific contingencies between the device and the child's actions or ways in which children physically interact with the screen. One additional word learning study highlights the unique role that giving children the ability to control their own experience plays in learning. Partridge, McGovern, Yung, and Kidd (2015) presented 3- to 5-year-olds with objects on a touchscreen that increased in size as a voiceover labeled them. In one condition children tapped a button in the center of the screen to trigger a labeling. In the other condition children tapped the specific object to trigger the labeling. Children were more accurate at identifying which object matched the label during on-screen testing if they had participated in the learning condition in which they tapped the specific object to hear the label. The authors concluded that the ability to self-direct learning through choice of where to tap increased engagement, increasing learning.

Research is still needed to best understand how many of the unique features of these devices impact learning. The initial studies reviewed here suggest that prior experience, self-regulation, motor skills, and other individual attributes play an important role in how well young children learn words from touchscreens. In addition, giving children the option to self-direct their learning is supportive, at least in some contexts.

## Language learning from electronic books

Beyond word learning, digital books may hold promise as educational tools to promote broader literacy skills. However, digital features in electronic books have been debated in the literature, with variations in these features both supporting and detracting from learning. Here I will focus on studies involving pre- and emergent readers, although certainly there is a growing literature regarding older children's and adults' learning from e-books (e.g., Ackerman & Goldsmith, 2011; Chan & Unsworth, 2011; Grimshaw, Dungworth, McKnight, & Morris, 2007; Huang, Liang, Su, & Chen, 2012; Kerr & Symons, 2006; Mangen, Walgermo, & Brønnick, 2013; Subrahmanyam et al., 2013; Wright, Fugett, & Caputa, 2013).

Almost two decades of research is now available on children's acquisition of language from computer books. Early digital books were CD-ROM books displayed on computers, and children used a mouse to navigate through the book. Zucker, Moody, and McKenna (2009) systematically reviewed the research on 2- to 12-year-old children's literacy and language learning from CD-ROM books, and found a small positive effect of electronic book use (versus a variety of comparison conditions) on comprehension outcomes. They did not find enough studies to draw a conclusion about other literacy outcomes. In addition, the authors noted that outcomes were not consistently positive across studies and argued that hotspots and animations could be used in ways that drew attention to the story, potentially supporting comprehension and language acquisition, or in ways that drew attention away from the story, potentially distracting the child from important information to be learned. A recent pilot study using a touchscreen book with and without hotspots also concluded that there was insufficient evidence regarding the pros and cons of hotspots for guiding children's attention or supporting comprehension (Piotrowski & Krcmar, 2017).

Takacs, Swart, and Bus (2015) proposed a distinction between supportive and distracting digital features. They reviewed 42 studies in which children ages 3 to 10 read electronic books with either multimedia features (animations and sounds) or interactive features (dictionaries,

hotspots, questions) or a comparison book without these features. The majority of the studies they reviewed featured CD-ROM books, but also included some touchscreen books. Children were assessed on literacy outcomes or observed for communicative behaviors during reading. Their results indicated that multimedia features were beneficial for story comprehension and expressive vocabulary, whereas interactive features had a negative impact. The authors concluded that interactive features distracted children from the story and increased cognitive load, whereas multimedia features guided attention and supported learning.

Beyond the support of built-in contingencies and features, it is also important to address the support of in-person co-readers who provide cues and scaffolds. In a separate meta-analysis, Takacs, Swart, and Bus (2014) reviewed 29 studies in which children ages 3 to 11 were assessed on vocabulary or story comprehension following exposure to an electronic book or a print book. They found that when they compared solitary electronic book reading to print reading by an adult who provided scaffolding, there was no difference in vocabulary or story comprehension outcomes. However, when solitary electronic reading was compared with solitary print reading, there was an advantage for electronic books for both vocabulary and comprehension. The authors concluded that multimedia features could support children's learning in a way similar to the scaffolds provided by adult co-readers, and noted that almost all of the studies they included involved electronic books that were enhanced with multimedia features like those that were supportive in the 2015 meta-analysis.

Thus far, the research on language acquisition from electronic books, despite being carried out with an older age group than most of the video word learning studies reviewed above, has resulted in a similar finding: that digital features, *when used well*, can help guide and support literacy learning. The natural next question is whether in-person scaffolds and social supports also enhance children's learning regardless of content, as they appear to do in video studies, or whether the multimedia features of books eliminate the benefit of co-users. Nardi (2016) provided a review of studies which included those from prior meta-analyses as well as an additional nine studies, including some in which parents supported both print and electronic reading. Nardi (2016) concluded that adult guidance was supportive in both print and electronic contexts. However, he also concluded that print reading with adult support was more effective than electronic reading with adult support due to distractions that electronic books provided. The nine additional studies reviewed by Nardi included mostly children on the younger end of the age range covered by the other reviews, which may suggest that electronic features play a differing role for pre-readers read to by adults than for children who are able to read the text themselves.

As Takacs and colleagues (2015) discussed, interactive features may draw attention away from important material. Several studies with American preschoolers have suggested that interactive features influence not just child attention, but also parent and child discussion during reading. Parish-Morris, Mahajan, Hirsh-Pasek, Golinkoff, and Collins (2013) reported that parents spent much more time talking about book features when reading a touch-sensitive electronic console book with their 3- and 5-year-olds than when reading print books, and less time talking about story content. There was also some evidence of lower story comprehension in 3-year-olds who read the console book compared to those who read print. Touchscreen books resulted in a similar pattern: Chiong, Ree, Takeuchi, and Erickson (2012) found that parents reading an interactive, enhanced touchscreen book with 3- to 6-year-olds did less labeling and pointing to elements of the story and spent more time talking about the physical features of the book itself. Children also had lower comprehension of the story when it was electronic rather than print. Even when adult talk was held somewhat constant because children read with a researcher, 3- to 5-year-olds talked more about the device and less about the story when reading an interactive electronic book than when reading print (Richter & Courage, 2017).

Yet there is evidence that it is not just interactive features, identified by Takacs and colleagues (2015) as reducing story comprehension and expressive language outcomes, which influence adult-child talk during reading. Simply the fact that electronic books are being read on a digital device appears to influence talk. Chiong and colleagues (2012) also included a comparison between print and basic e-books without interactive features. Adults still talked more about book features when the book was electronic rather than print. This pattern was confirmed by Krcmar and Cingel (2014), who had 2- to 5-year-olds read basic touchscreen books without any interactive enhancements and print books with their parents. In the touchscreen book condition, child comprehension was lower and parents spent more time off-topic or talking about the book format. In these studies, which focus on parent-child interaction in a younger age group than many of the studies reviewed by Takacs and colleagues (2014, 2015), simply using a digital device may have distracted parents and children from focusing on story content. Features of navigation, like how to turn the page or hold the device, may draw attention away from a story-focused reading experience.

Future research is needed to better understand whether other factors, such as feeling that electronic books are already educational and do not require parent support, also influence the support parents provide during electronic reading. In a survey of parents of children ages 1 to 4 years who read both print and electronic books, parents indicated that they much more frequently practiced supportive behaviors during print than electronic reading stories (Strouse & Ganea, 2017a). For example, 76% of parents said they typically point to and label items in print stories, whereas 34% of the same parents typically pointed to and labeled items in electronic stories; 66% of parents reported stopping to discuss stories when reading print books, but only 26% of parents said they did this with electronic books.

Despite the fact that interactive features may disrupt story talk, they may help to increase child engagement with books. Richter and Courage (2017) reported that children in their study were more attentive to and engaged with the electronic than the print book and spent more time with it. A similar finding was reported by Moody, Justice, and Cabell (2010), when Head Start children persisted longer when reading CD-ROM than print books with a researcher. Strouse and Ganea (2017c), the only researchers to look at parent-child electronic reading in toddlers, found that toddlers spent more time, were more attentive, displayed more positive affect, and produced more comments about the book when reading touchscreen than print books. Thus, digital platforms may be more engaging for young readers. As with the engagement-enhancing effect of video chat, it is important for future research to investigate the long-term impact of increased engagement on learning from digital books over time to determine whether it translates into benefits for learning.

Like the research on shared print reading, much of the literature on shared digital reading has been focused on somewhat older children than the literature I have reviewed on learning from video. It has thus involved early literacy outcomes including vocabulary, comprehension, and phonological skills. Interestingly, it has resulted in somewhat parallel conclusions: that digital enhancements built into the medium have potential to support learning, that some enhancements that lead to increased engagement do not necessarily translate into enhanced learning, and that additional support provided by adults may be incrementally effective.

## Conclusion

Screen media presents both challenges and opportunities for young children's language development. Some issues are applicable across many different media types. First, children may struggle to recognize similarities across contextual mismatch, which could lead to failure activating or

applying memories encoded from screens in new contexts. Second, children need conceptual insight regarding which information from screens is to be learned, generalized, and transferred to new settings, and which unrealistic information is meant to be quarantined in media worlds. Finally, social cues are an important component of young children's language acquisition, and are absent in many media contexts. Including on-screen speakers who can provide social cues to reference is one method for supporting word learning from video. Other cues to reference, such as animation and repetitive contexts, can be supportive in the absence of social cues, but special care should be taken to make sure they are synchronous and do not distract from the information to be learned. In-person co-viewers can provide additional supports to young learners beyond the ones provided in media itself.

In addition to these common themes across media, touchscreens provide some unique affordances that allow children to physically interact with and control content on screen. For example, allowing children to choose the order in which they viewed content was supportive of word learning. Other initial word learning studies indicate that there may be significant individual differences in learning from touchscreens. Aspects that may predict learning include prior experience, motor skills, self-regulation, and working memory or general cognitive processing.

Finally, electronic books have been found to promote early literacy skills above and beyond solitary print reading. Multimedia enhancements (animations, sounds) in electronic books are supportive of vocabulary and comprehension, whereas interactive features like hotspots and games have been shown to be detrimental. In addition to distracting children, some electronic features may also distract parents when reading with their children, leading to significant changes in parent and child story talk, and lower child story comprehension. Future research should address reasons for differences in parent-child talk which appear even in the absence of interactive digital features.

Additional research on the experiences and contexts that support children's learning from media is needed to better inform new policies, such as the recommendations put out by the American Academy of Pediatrics (Hill et al., 2016) and the National Association for the Education of Young Children (Radich, 2013). Better understanding of individual differences in learning from media may also help support development of digital devices as learning tools in particular contexts or populations, for example, to support children with autism in communicating with peers and adults (Holt & Yuill, 2014), or to support vocabulary acquisition in children with cochlear implants (Messier & Wood, 2015). In addition, research on which types and features of digital media support learning can help parents and teachers choose high-quality media for children. Initial work in this area (Common Sense, n.d.; Hirsh-Pasek et al., 2015) has made important strides toward this goal. Ultimately, young children in today's society are exposed to a wide variety of digital media experiences, so it is important for researchers, policy makers, and media producers to work together to promote the most supportive contexts and content for healthy development.

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# 26

# THE CO-DEVELOPMENT OF VOCABULARY AND READING COMPREHENSION

*Richard K. Wagner and Jamie M. Quinn*

## Vocabulary and reading comprehension

The goal of reading is to comprehend the author's intended meaning. To do so, one must understand the meanings of the individual words as well as the meanings implied by combinations of words used (National Institute of Child Health and Human Development, 2000). That vocabulary – understanding the meanings of individual words – and reading comprehension – understanding the meanings implied by combinations of words – are related has been established over decades of correlational research. Typical correlations between vocabulary and reading comprehension fall in the range from .30 to .80 (Tannenbaum, Torgesen, & Wagner, 2006).

A number of variables appear to affect the strength of the reported correlation. For example, the magnitude of the correlation between vocabulary and reading comprehension increases with age. Snow (2002) reported correlations between vocabulary measured in kindergarten and reading comprehension of .45 in first grade, .62 in fourth grade, and .69 in seventh grade. When vocabulary is assessed using a group-administered test that requires reading the words and definitions, correlations with reading comprehension are higher because individual differences in reading can affect the vocabulary score to a greater degree than when vocabulary is measured orally (Hafner, Weaver, & Powell, 1970; Stanovich & Cunningham, 1992). Another possible explanation of differences in the strength of correlations between vocabulary and reading comprehension is how vocabulary knowledge is conceptualized and measured in different studies.

## How should we conceptualize vocabulary knowledge?

Is vocabulary knowledge one thing, or are there different kinds? Should we think of it as word-specific knowledge or as the long-term product of inference applied to language experience? An adequate conceptualization of vocabulary knowledge might help explain variability in observed correlations between vocabulary and reading comprehension.

Common vocabulary measures such as the Peabody Picture Vocabulary Test (Dunn & Dunn, 1997) are assumed to measure breadth of vocabulary knowledge. Breadth of vocabulary knowledge refers to how many words have meanings for an individual, or the size of an individual's mental lexicon (Anderson & Freebody, 1981). Alternatively, one might assess depth of knowledge

about words an individual knows. Depth can range from only being able to 1. recognize that a word indeed is a word but not being able to define or use it, 2. define a word, 3. know multiple definitions of a word, and 4. know relations between a word and other words (Anderson & Freebody, 1981; Beck, McKeown, & Kucan, 2002; Stahl, 1998). A confirmatory factor analysis of multiple measures of vocabulary knowledge given to third-grade students supported breadth and depth as two distinct yet correlated dimensions of vocabulary knowledge (Tannenbaum et al., 2006).

Spencer et al. (2015) reported results from two studies that have implications for a conceptualization of vocabulary knowledge. Both studies included multiple measures of morphological awareness as well as vocabulary knowledge. Morphological awareness refers to the ability to recognize and manipulate morphemes, which are the component building blocks of word meanings such as prefixes, suffixes, and word roots (Carlisle, 1995). Because alphabetic languages such as English are considered morphophonemic scripts with spellings reflecting both meaning and pronunciation, morphological awareness is believed to be predictive of success in reading (Carlisle, 2000, 2003). More vocabulary words are learned incidentally when they are encountered from listening or reading than from direct instruction (see Chapter 22, this volume; Chapter 24, this volume), and morphological knowledge and context are two sources of helpful information about an unfamiliar word's meaning (Carlisle, 2007; Nagy & Scott, 1990). It has been estimated that 60 percent of unfamiliar words a reader encounters have meanings that can be predicted by knowing their component morphemes (Nagy & Anderson, 1984).

In the first study, Spencer et al. (2015) used confirmatory factor analysis to test alternative models of the nature of morphological awareness and its relation to vocabulary knowledge. They gave nine experimenter-created morphological awareness tasks and two standardized measures of vocabulary to a sample of English-speaking fourth-grade students.

Five of the morphological awareness tasks involved the use of derivational morphology:

1 Decomposition (Carlisle, 2000). "The word is *driver*. The sentence is: Children are too young to _____" (*drive*).
2 Derivation (Carlisle, 2000). "The word is *farm*. The sentence is: My uncle is a _____" (*farmer*).
3 Derivational suffix choice for real words (University of Washington, 1999). "Did you hear the _____? (a) announce, (b) announcing, (c) announced, (d) announcement."
4 Derivational suffix choice for nonwords (University of Washington, 1999). "Our teacher taught us how to _____ long words. (a) *jittling*, (b) *jittles*, (c) *jittle*, (d) *jittled*."
5 Derivational suffix choice with improbable suffixes (University of Washington, 1999). "The item is dogless: (a) The dogless can run fast. (b) He was in the dogless. (c) He was no longer dogless. (d) He did not try to dogless."

The remaining four morphological awareness tasks involved free morphemes:

6 Bee grass task (Elbro & Arnbak, 1996; Fowler & Liberman, 1995). "Which is a better name for a bee that lives in the grass? A *grass bee* or a *bee grass*?"
7 Comes-from task (Berko, 1958; Carlisle, 1995; Derwing, 1976; Mahony, 1994; Mahony et al., 2000). "Does *quickly* come from *quick*? Does *mother* come from *moth*?"
8 Morpheme identification (McBride-Chang, Wagner, Muse, Chow, & Shu, 2005). "Which contains the meaning of the *steak* in *steakhouse*?" (examinee is then shown pictures of a steak and a stake and picks the correct response).

9 Morphological construction (Mc-Bride-Chang et al., 2005). "Early in the morning we can see the sun coming up. This is called *sunrise*. At night, we might also see the moon coming up. What could we call this?" (*moonrise*).

Two standardized vocabulary tasks were administered: the Vocabulary subtest from the *Stanford-Binet 4th ed*. (Thorndike, Hagen, & Sattler, 1986) and the *Peabody Picture Vocabulary Test* (Dunn & Dunn, 1997).

The morphological awareness tasks differed in format of administration – oral versus written – and response – multiple-choice versus produce the correct answer. A single-factor model fit the covariances among the morphological tasks quite well, with a chi-square of 25.47 with 26 degrees of freedom, $p = .49$, Confirmatory Fit Index (CFI) = 1.00, Tucker-Lewis Index (TLI) = 1.00, Root Mean Square Error of Approximation (RMSEA) < .001 with the probability of an excellent fit of .78. Neither the two-factor model that specified oral versus written administration as two correlated yet distinct factors, nor the one that specified multiple-choice versus productive responses as two correlated yet distinct factors, provided a significantly better fit than the single-factor model.

The vocabulary tests were then added to the model, and two alternative models of relations between morphological awareness and vocabulary knowledge were tested. The first model specified that morphological awareness and vocabulary were distinct although potentially related constructs. The second specified that the morphological awareness tasks and the vocabulary tasks were measuring the same underlying construct. Prior results in the literature have been mixed, with some studies finding that morphological awareness and vocabulary were measuring the same underlying construct (e.g., Nagy et al., 2003) and others supporting them as distinct although correlated skills (e.g., Ramirez, Walton, & Roberts, 2014). The single-factor model that posited no differences in the underlying construct measured by morphological awareness and vocabulary tasks fit the data as well as did a two-factor model that specified distinct yet potentially correlated skills. These results indicated that the correlation between morphological awareness and vocabulary knowledge was not significantly different from 1.0. The morphological awareness and vocabulary tasks were measuring the same underlying construct.

A limitation of study one was that vocabulary knowledge was represented by only two tasks that both measured definitional knowledge, or one's ability to define a word. Because only a single definition was required, the tasks were measuring breadth of vocabulary knowledge. Morphological awareness might be related differently to other kinds of vocabulary knowledge such as usage (i.e., one's ability to use a word in context) or relational knowledge (i.e., one's ability to identify antonyms and synonyms). A second limitation of study one, which is a limitation shared by all other existing studies in the literature of which we are aware, was that the different tasks had different words on them. Differential knowledge of the specific vocabulary words that were the basis of task items could affect the magnitude of the correlations among the tasks, thereby affecting the results of confirmatory factor analyses or any other analyses based on task covariances or correlations. For example, differential knowledge of specific vocabulary words that are items on various tasks might inflate the observed correlations among the tasks. For a common word such as "slow," it may be relatively easy to provide a definition, use it in a sentence, identify antonyms and synonyms, and provide a morphologically related variant such as "slower". On the other hand, for a rare word such as "legate" (referring to a representative of the Pope or an envoy), it may be difficult to provide a definition, use it in a sentence, identify antonyms and synonyms, and provide a morphologically related variant such as "legation" or "delegate." If this is the case, differential familiarity with the vocabulary words used on the tasks would inflate the correlations among the different tasks.

Two issues from study one were addressed in study two: 1. differential knowledge of the specific vocabulary words and 2. measuring vocabulary knowledge in only one way (measuring only definitional knowledge, or breadth of vocabulary). In study two, an identical set of 23 vocabulary words was used on multiple vocabulary-related tasks that assessed different kinds of vocabulary knowledge. Definitional knowledge was assessed by asking for a definition ("Tell me what _____ means.") and then for a second definition that showed knowledge of an alternative meaning ("Tell me another definition of the word _____."). The purpose of asking for a second definition was to assess depth as well as breadth of definitional knowledge. Word usage was assessed by asking for a word to be used in a sentence ("Give me a sentence using the word _____.") and then in a second sentence ("Give me another sentence that uses a different meaning of the word _____."). Word relatedness was assessed by asking for synonyms ("Give me words that mean the same as _____.") and antonyms ("Give me words that mean the opposite of _____."). Two morphological awareness tasks were also given. A morphological completion task provided a target word and a sentence that required a morphologically related variant of the target word ("The word is light. The sentence is 'Her mom _____ the birthday candles."). A morphological generation task required generating as many morphological variants of a target word as possible ("Give me other words you can get by changing the word _____.").

All eight tasks, each with the identical set of 23 vocabulary words, were given to 90 English-speaking eighth graders who were involved in a larger reading comprehension study. To analyze the data, eight by eight correlational matrices (based on the eight items) were created for each of the 23 words. These correlational matrices were then averaged together to form a composite correlation matrix. Confirmatory factor analyses of the composite correlation matrix were used to test three alternative models of vocabulary knowledge. The first was a one-factor model that was specified as a single latent variable with all eight vocabulary and morphological awareness tasks as its observed indicators. The second was a two-factor model that was specified by having the six vocabulary knowledge items loading on a vocabulary latent variable and the two morphological awareness tasks loading on a morphological awareness latent variable, with the two latent variables permitted to be correlated. Finally, a four-factor model was specified by having latent variables representing definitional knowledge, usage, relational knowledge, and morphological awareness, each with their respective pairs of items as observed indicators.

The result was that the one-factor model provided an excellent fit to the data. The chi-square value of 11.77 was considerably less than the model's 20 degrees of freedom, with a probability that the model provided a perfect fit to the population data of 0.92. The Root Mean Squared Error of Approximation (RMSEA) was less than .001 with a probability of an excellent fitting model of .98. The Tucker-Lewis Index (TLI) and the Comparative Fit Index (CFI) were both at their maximum possible values of 1.00. Chi-square difference tests showed that the two- and four-factor models did not provide a significantly better fit than the more constrained one-factor model.

In summary, the results of the first study were that a single underlying dimension accounted for individual differences in the nine morphological awareness tasks and two definitional vocabulary tasks that were given. The results of the second study extended the results of the first study by incorporating a wider variety of vocabulary measures and by adding a new morphological awareness task. This study also controlled for the possible effects of differential knowledge of the specific vocabulary words that were present on the different tasks by using the identical set of words for each task. The results again were that a single underlying dimension accounted for individual differences in all of the vocabulary and morphological awareness tasks that were given.

Our interpretation of these results is that definitional knowledge, the ability to use words in sentences, the ability to identify antonyms and synonyms, and the ability to identify

morphologically related variants of words are all facets of knowledge about words that are acquired when words are encountered in context. That is to say, when words are learned from listening or reading, what one learns about the words can be used for defining the words, using them in sentences, identifying antonyms and synonyms, and identifying morphologically related variants.

In addition to the fact that variability in observed correlations between vocabulary knowledge and reading comprehension might be explained in part by the kind of vocabulary measures that are given, it is also likely to be the case that variability in observed correlations might be explained by the kinds of reading comprehension measures that are given. Correlations between different reading comprehension tests given to the same individuals can be surprisingly modest (Keenan, Betjemann, & Olson, 2008; Keenan, Olson, & Betjemann, 2009; Muijselaar, Kendeou, de Jong, & van den Broek, 2017; Papadopoulos, Kendeou, & Shiakalli, 2014). Different reading comprehension tasks differentially weight the importance of decoding and oral language comprehension. Spooner, Baddeley, and Gathercole (2004) argued that the Neale Analysis of Reading Ability (NARA, Neale, 1997), a standardized measure of reading ability widely used in the UK, puts a large emphasis on word reading skills in measuring a child's comprehension skills. Relatedly, cloze tasks, which require a child to replace a word that has been removed, are also dependent on a child's word reading ability. Unless word reading skills are accounted for, it is difficult to determine if difficulties on a reading comprehension task are specific to word decoding or to problems with globally understanding the passage (Cain & Oakhill, 2006). Alternatively, vocabulary knowledge might be more important for some kinds of comprehension tasks than for others (Cain & Oakhill, 2014). Reading comprehension tasks with open-ended questions might be particularly difficult for students with expressive language problems (Cain & Oakhill, 2006).

## Alternative explanations for observed correlations between vocabulary and reading comprehension

Anderson and Freebody (1981) were among the first to consider alternative explanations for observed correlations between vocabulary and reading comprehension. They proposed three alternative explanations in the form of hypotheses. The instrumentalist hypothesis posits a causal influence of vocabulary on reading comprehension: The better one knows the meanings of the individual words one is reading, the better one will grasp the meaning of the passage. More recent versions of this idea exist in positing that lexical knowledge, in the form of the precision of one's orthographic, phonological, and semantic representations, plays an important role in comprehension (Perfetti & Hart, 2001; Verhoeven & van Leeuwe, 2008). Anderson and Freebody's remaining two hypotheses posited correlational rather than causal explanations for observed correlations between vocabulary and reading comprehension. The knowledge hypothesis posits that vocabulary and reading comprehension are correlated because they both are related to the third variable of conceptual knowledge. The more conceptual knowledge you have, the better you will do on both vocabulary and reading comprehension measures. The aptitude hypothesis posits that vocabulary and reading comprehension are correlated because they both are related to the third variable of verbal aptitude. This view is supported by the fact that the single best predictor of verbal IQ is vocabulary (Sattler, 2001), and there also is a strong correlation between verbal IQ and reading comprehension (Woodcock, McGrew, & Mather, 2001/2007).

There are other alternative explanations for the correlation between vocabulary and reading comprehension that Anderson and Freebody (1981) did not describe. One possibility is that there could be an instrumental relation pointing in the other direction, with reading

comprehension having an instrumental relation to vocabulary (Wagner & Meros, 2010). Much of one's vocabulary is acquired from context, including from reading, and individual differences in reading comprehension could result in differential ability to infer or sharpen the meanings of words that are encountered in text (Cain, 2007; Cain & Oakhill, 2011; Currie & Cain, 2015; Nagy & Scott, 2000; Nation, Snowling, & Clarke, 2007). Another possibility is that there is an instrumental effect of vocabulary on reading comprehension, but the effect is mediated rather than direct. For example, performance on both phonological awareness tasks and decoding measures is better for known vocabulary words than for nonwords. Being better able to decode the words on the page because they are known vocabulary words would likely improve comprehension (Wagner & Meros, 2010). Morphological awareness and vocabulary knowledge also contribute to derivational word reading for middle school students (Goodwin, Gilbert, & Cho, 2013). Inference skills could also mediate the role of vocabulary in reading comprehension (Daugaard, Cain, & Elbro, 2017). In addition to main effects or mediated relations, the effects of word reading skills may be different for different individuals (i.e., moderation). For example, morphological awareness may be more important for skilled reading comprehension for students with poor multisyllabic word reading skills (Gilbert, Goodwin, Compton, & Kearns, 2014). Finally, it is possible that the correlation between vocabulary and reading comprehension derives in part because they are both related to the third variable of metalinguistic awareness. As mentioned earlier, morphological awareness, which is a form of metalinguistic awareness, is an important aspect of vocabulary knowledge (Spencer et al., 2015). A second form of metalinguistic awareness, metacognition, is believed to be an important aspect of reading comprehension (Nagy, 2007).

One way to test for possible instrumental relations between vocabulary and reading comprehension would be a training study in which either vocabulary or reading comprehension is manipulated and then an effect is either observed or not in the corresponding variable. Results from meta-analyses of the effects of vocabulary training on comprehension have been inconclusive (Stahl & Fairbanks, 1986; Elleman, Lindo, Morphy, & Compton, 2009). Moderate effects of vocabulary training have been observed on experimenter-created measures of comprehension that were designed to be sensitive to the specific training program being used but with no real effects on broader, standardized measures of reading comprehension. Of course, it is possible for instrumental relations to exist, but it is not easy to manipulate vocabulary or reading comprehension via training programs. Alternatively, it may be the case that manipulation is possible to some degree but commonly used standardized measures of vocabulary and reading comprehension are not sensitive to the magnitude of manipulation effects that can be readily obtained.

Vocabulary and reading comprehension appear to be difficult to manipulate through relatively short-term training efforts. One way to further our understanding of relations between constructs is to take advantage of the fact that they still show considerable change over normal development. Specifically, the idea is to study relations between vocabulary and reading comprehension through analyzing data from longitudinal studies.

Longitudinal predictive studies show that vocabulary indeed predicts subsequent reading comprehension (e.g., Muter, Hulme, Snowling, & Stevenson, 2004; Oakhill, Cain, & Bryant, 2003). However, employing structural equation causal modeling in which the autoregressor of reading comprehension at time one is also included with vocabulary as a predictor of reading comprehension at time two provides a stronger test of whether vocabulary predicts subsequent reading comprehension than do simple longitudinal correlations. If the autoregressor of reading comprehension at time one is excluded as a predictor of reading comprehension at time two, vocabulary at time one can show up as a spurious predictor because it is correlated with the unmeasured causal influence of reading comprehension at time one on reading comprehension

at time two. Two studies using structural equation causal modeling with the autoregressor effect included found important predictive effects. De Jong and van der Leij (2002) reported that vocabulary in third grade predicted fifth-grade reading comprehension after controlling for third-grade reading comprehension. Verhoeven and van Leeuwe (2008) reported a strong predictive effect for vocabulary on later reading comprehension, and a weaker effect of reading comprehension on subsequent vocabulary for models that included the autoregressor variable.

A strength of these kinds of structural equation causal models when applied to longitudinal data is that time precedence supports making causal inferences from the results. Because the developmental period under study is divided into discrete intervals, it is possible to answer the question of whether, say, reading comprehension at time one accounts for variance in vocabulary at time two after controlling for the autoregressor effect of vocabulary at time one. A weakness of these models is that means are ignored, and only individual differences in the form of covariances are modeled. Consequently, identical results would be found if performance on both constructs being studied goes up over development, if performance on both constructs goes down over development, or if performance on one construct goes up and performance on the other goes down.

An alternative method for analyzing data called latent growth curve models addresses the weakness of longitudinal structural equation causal models that means are not modeled by explicitly including a growth function that models change in performance over time. Means as well as covariances are modeled, and the results depend in part on whether the constructs increase or decrease over time. However, a weakness of latent growth curve models is that time precedence no longer is available for supporting causal influences. A single growth curve parameter is available to model growth across the entire developmental period. One can look for predictors of individual differences in the growth curve parameter, but it is no longer possible to determine whether a construct at time one accounts for variance in another construct at time two with appropriate controls in place.

Another form of analysis called latent change score modeling provides a much stronger test of potential influences of one construct on the development of a second construct (Ferrer & McArdle, 2010; McArdle, 2009). Latent change score modeling combines the just identified strengths of structural equation causal models and latent growth curve models and eliminates their weaknesses. Overall development is segmented into change from one discrete time interval to the next; time precedence is available to support causal inference. Because means as well as covariances are modeled, all of the data are used, and the results address growth as well as individual differences.

Quinn, Wagner, Petscher, and Lopez (2015) used latent change score modeling to study development relations between vocabulary and reading comprehension. Participants in the study were 316 students who were assessed annually from first through fourth grade as part of the Florida Longitudinal Study. Each year, two measures of vocabulary and two measures of reading comprehension were given, thereby allowing us to represent both constructs as latent variables with two observed indicators.

For correlated constructs like vocabulary and reading comprehension, it is typically the case that intercepts or initial status in the two constructs is correlated. This just means that individuals who score well on vocabulary at the initial time point will also score well on reading comprehension at the initial time point. It is also common for slope or growth to be correlated. Individuals who grow fast in vocabulary across the developmental window also tend to grow fast in reading comprehension. Latent change score models account for potentially correlated intercepts and slopes by allowing and estimating covariances between these parameters. More interesting, however, is that latent change score models also estimate possible direct influences of one construct on the development of another construct that are independent of the correlated intercepts and growth. The models do so by including coupling parameters. The terms leading

and lagging indicators are used to describe these potential relations between constructs. A construct is said to be a leading indicator for a second construct if level of performance or growth on the first construct accounts for variance in subsequent growth in the second construct. In this case the second construct is considered to be a lagging indicator of the first construct. Four competing models of developmental relations between vocabulary and reading comprehension were tested. We present these in the following sections.

### *Potentially correlated but uncoupled development*

This model allows for individual differences and growth in vocabulary and reading comprehension to be correlated, but no direct influences or coupled development. This model can account for the possibility that individuals who are high in vocabulary also tend to be high in reading comprehension. It can also account for the possibility that individuals who grow faster in vocabulary also tend to grow faster in reading comprehension. But it does not allow for the possibility that level of performance or growth in, say, vocabulary accounts for subsequent growth in reading comprehension, or vice versa, independent of what is explained by their correlated status and growth. Explanations of correlations between vocabulary and reading comprehension such as Anderson and Freebody's (1981) conceptual knowledge or aptitude hypotheses, in which the correlation is explained by both vocabulary and reading comprehension being correlated with a third variable such as conceptual knowledge or verbal aptitude, would be consistent with the potentially correlated but uncoupled development model. This model is implemented as a latent change score model in which 1. a covariance is estimated between the intercepts of vocabulary and reading comprehension, 2. a covariance is estimated between the slopes of vocabulary and reading comprehension, but 3. no coupling parameters are included in the model.

### *Unidirectional coupling from reading comprehension to vocabulary*

Much of our vocabulary knowledge is acquired from coming across vocabulary in context when reading or when listening to people talking. For vocabulary encountered when reading, being good at reading comprehension may help you better infer the meanings of new words you come across or sharpen or add to the meanings of words you have some familiarity with. In this way, individual differences in reading comprehension could explain subsequent development in vocabulary. This model is consistent with an instrumental relation between reading comprehension and vocabulary but in the opposite direction of Anderson and Freebody's instrumental hypothesis. Like the potentially correlated but uncoupled development model, the unidirectional coupling from comprehension to vocabulary model allows for individual differences and growth in vocabulary and reading comprehension to be correlated, but also allows direct influences from reading comprehension to vocabulary that are independent of correlations between individual differences and growth. This model is implemented as a latent change score model in which 1. a covariance is estimated between the intercepts of vocabulary and reading comprehension, 2. a covariance is estimated between the slopes of vocabulary and reading comprehension, 3. coupling parameters are included in the model from reading comprehension to subsequent change in vocabulary, but 4. no coupling parameters from vocabulary to reading comprehension are included.

### *Unidirectional coupling from vocabulary to reading comprehension*

If you have a rich vocabulary, you are likely to be better able to understand the intended meaning in texts that you read, and thereby comprehend what you read better than someone who

lacks some vocabulary knowledge represented in a text. If this is true, having rich vocabulary knowledge could result in improved reading comprehension over time. This model is consistent with Anderson and Freebody's instrumental hypothesis. This model allows for individual differences and growth in vocabulary and reading comprehension to be correlated, but also allows direct influences from vocabulary to reading comprehension that are independent of correlations between individual differences and growth. This model is implemented as a latent change score model in which 1. a covariance is estimated between the intercepts of vocabulary and reading comprehension, 2. a covariance is estimated between the slopes of vocabulary and reading comprehension, 3. coupling parameters are included in the model from vocabulary to reading comprehension, but 4. no coupling parameters from reading comprehension to vocabulary are included.

### *Bidirectional coupling between vocabulary and reading comprehension*

This model combines the coupling parameters of the unidirectional coupling from reading comprehension to vocabulary and the unidirectional coupling from vocabulary to reading comprehension models. This model is implemented as a latent change score model in which 1. a covariance is estimated between the intercepts of vocabulary and reading comprehension, 2. a covariance is estimated between the slopes of vocabulary and reading comprehension, 3. coupling parameters are included in the model from vocabulary to reading comprehension, and 4. coupling parameters from reading comprehension to vocabulary are also included.

Prior to running the four competing bivariate models, three alternative univariate models were run separately for vocabulary and reading comprehension to determine which model best characterized growth for each construct. A constant change model posited that rate of growth was linear. A proportional change model posited that rate of growth was proportional to the previous level of performance. Finally, a dual-change model positively modeled growth as a function of both linear and proportional change elements.

Beginning with the univariate modeling results, a dual-change model fit the data best for both vocabulary (see Figure 26.1) and reading comprehension (see Figure 26.2). Chi-square difference testing showed that the constant change model and the proportional change models provided significantly worse fits to the data. Looking at the parameter values for these models, there was significant variability in the initial means for both vocabulary and reading comprehension, indicating that participants varied substantially in their initial levels of performance. Growth in both vocabulary (0.79) and reading comprehension (1.04) was significant, as was the amount of variability in rates of growth for both vocabulary (0.04) and reading comprehension (0.07). The proportional change coefficients were significant and negative for both vocabulary (−0.08) and reading comprehension (−0.42), indicating that rate of growth slowed over time. Finally, fan spread growth (i.e., higher initial performers grew faster) was indicated by the positive correlations between intercept and slope for both vocabulary (0.29) and reading comprehension (0.62).

Turning to the bivariate models, the univariate coupling from vocabulary to reading comprehension model (see Figure 26.3) provided the best fit to the data. All of the values reported in the figure were significant at the .05 level or beyond. Beginning with the left side of the figure, initial levels of vocabulary and reading comprehension were correlated strongly (0.66). Students who scored well on the vocabulary measures at the beginning of the study also tended to score well on the reading comprehension measures; conversely, students who scored more poorly on the vocabulary measures also tended to score more poorly on the reading

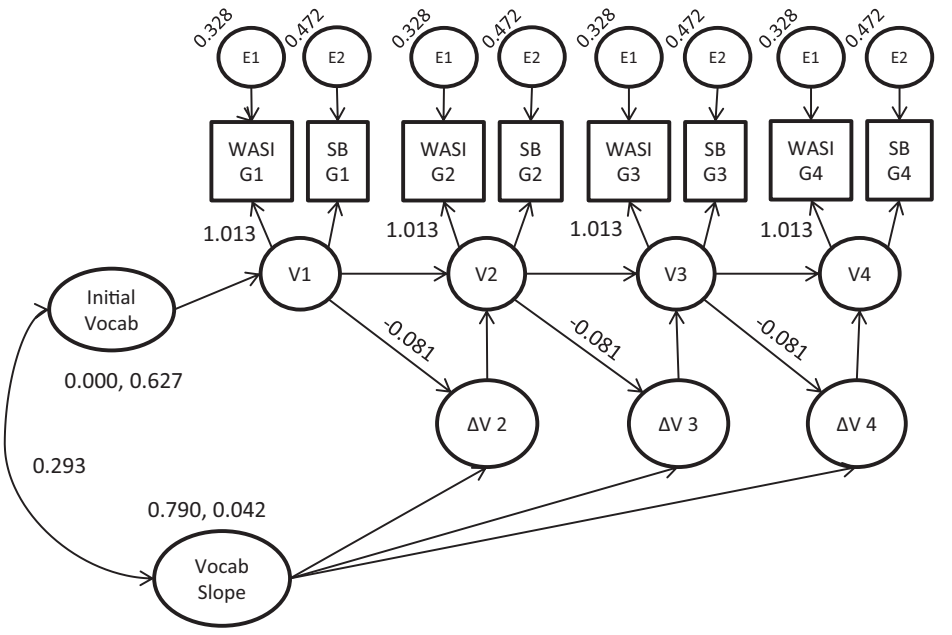



*Figure 26.1* Univariate dual-change score model of vocabulary knowledge growth.

*Note*: WASI = Weschler Abbreviated Scales of Intelligence - Vocabulary; SB = Stanford-Binet Vocabulary; G1-G4 = Grade 1 through Grade 4;V1-V4 = latent vocabulary knowledge at grades 1-4; ΔV = change in vocabulary; E1, E2 = error variances.

comprehension measures. This just shows that the commonly observed positive correlation between vocabulary and reading comprehension measures held for this sample and for these measures. There was a moderately strong positive correlation between vocabulary slope and reading comprehension slope. Students who grew relatively faster on the vocabulary measures over the four years of the study also tended to grow relatively faster on the measures of reading comprehension; students who grew relatively slower tended to do so on both vocabulary and reading comprehension. This result was also expected. Presumably, one reason why vocabulary and reading comprehension were correlated positively at the beginning of the study was a result of a positive correlation between growth on the two constructs that occurred prior to the beginning of the study.

Of greater interest was whether cross-lag effects would be observed. There was a positive cross-lagged effect (0.18) from vocabulary to subsequent growth in reading comprehension. What this means is that independent of the correlations between initial performance and rates of growth in vocabulary and reading comprehension, there was an additional direct effect from vocabulary to change in reading comprehension. How much year to year growth occurred in reading comprehension was explained in part by vocabulary performance. Although the magnitude of this effect seems relatively small at first glance, it is important to remember that the effect of 0.18 was for each year rather than for the entire four years of the developmental period. Cumulatively, the effect was 0.55, which is substantial. The observed cross-lag effect from vocabulary to change in reading comprehension is consistent with the idea that a rich vocabulary makes it possible to comprehend what one reads more fully, and that doing so over time improves one's reading comprehension. These results are consistent with Anderson and Freebody's instrumental hypothesis. There was no evidence of cross-lag effects from reading comprehension to vocabulary.

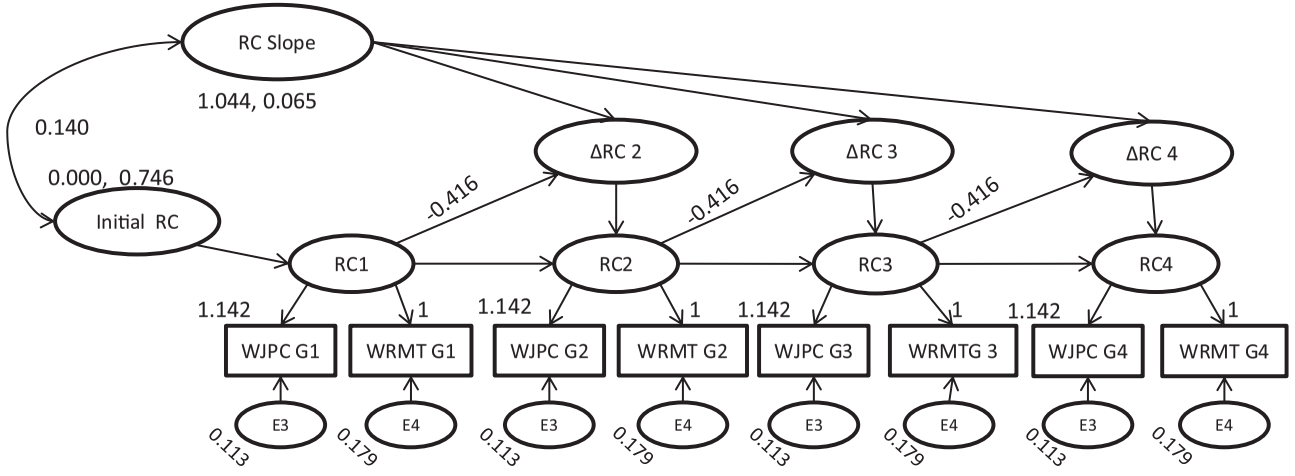



*Figure 26.2* Univariate dual-change score model of reading comprehension growth.

*Note*: WJPC = Woodcock Johnson Passage Comprehension; WRMT = Woodcock Reading Mastery Test; G1-G4 = Grade 1 through Grade 4; RC1-RC4 = latent reading comprehension at grades 1-4; ΔRC = change in reading comprehension; E3, E4 = error variances.

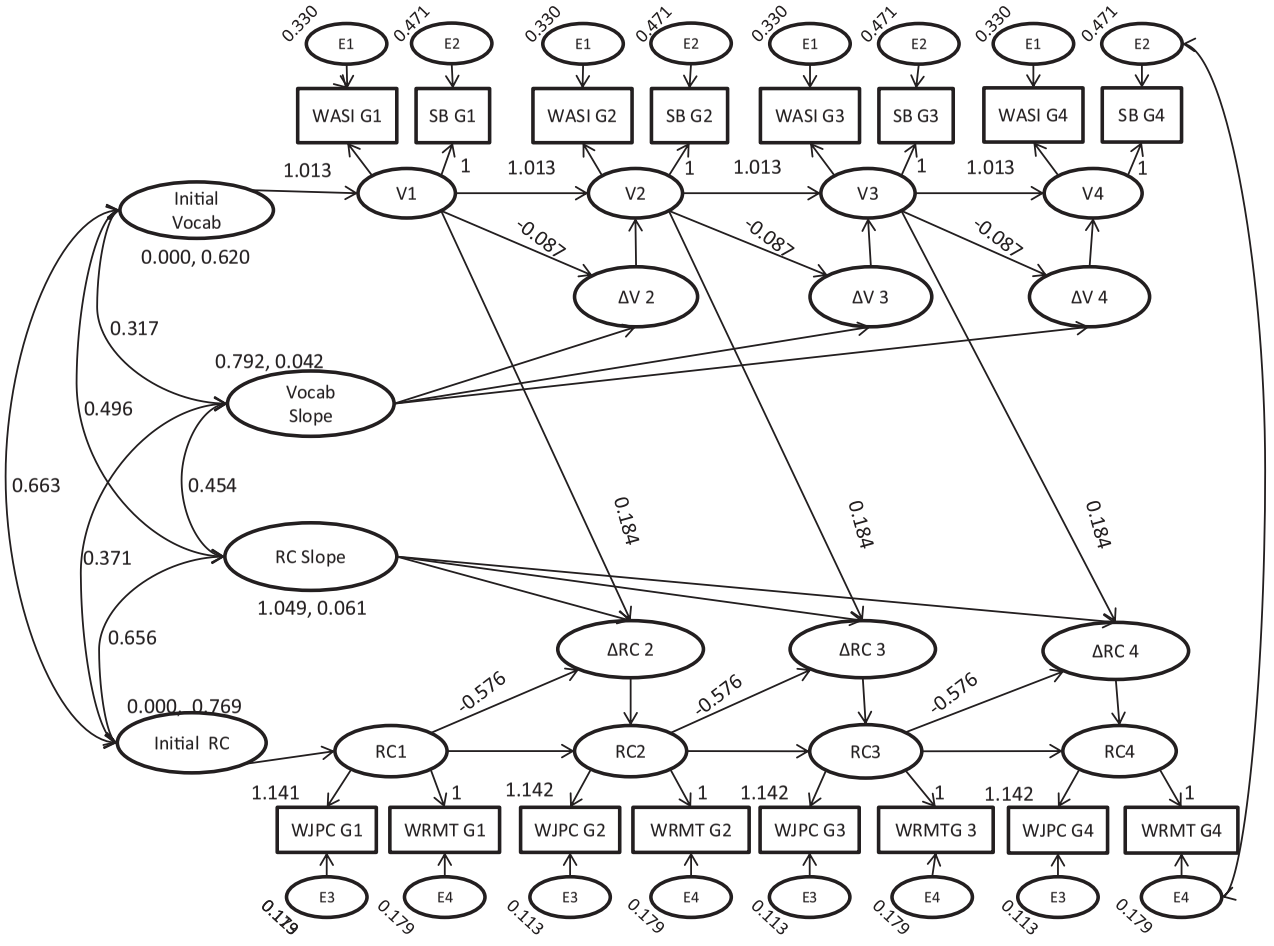



*Figure 26.3* Bivariate dual-change score model with unidirectional coupling from vocabulary knowledge to change in reading comprehension.

*Note*: WASI = Weschler Abbreviated Scales of Intelligence - Vocabulary; SB = Stanford-Binet Vocabulary; G1-G4 = Grade 1 through Grade 4; V1-V4 = latent vocabulary knowledge at grades 1-4; WJPC = Woodcock Johnson Passage Comprehension; WRMT = Woodcock Reading Mastery Test; RC1-RC4 = latent reading comprehension at grades 1-4; ΔV = change in vocabulary; ΔRC = change in reading comprehension; E1-E4 = error variances.

In summary, the results of Quinn et al. (2015) support the importance of vocabulary for reading comprehension. By applying a relatively new way of analyzing developmental data, we found an effect of vocabulary on subsequent growth in reading comprehension that was independent of the commonly observed correlations between individual differences in vocabulary and reading comprehension and also independent of the correlated rates of growth between the two constructs. Their results are consistent with several other studies. Ferrer et al. (2007) reported results from a latent change score modeling analysis of data from the Connecticut Longitudinal Study, a longitudinal study of over 400 students who were followed from 1st through 12th grade. The two constructs they examined were IQ and a reading composite consisting of accuracy of word and nonword decoding and reading comprehension. They reported a cross-lag effect from IQ to reading comprehension, but also a cross-lag effect from reading comprehension to IQ. The effects were stronger for performance IQ than for verbal IQ, and for younger children compared to older children. They also replicated these findings using verbal IQ and reading comprehension, constructs that are more similar to those used by Quinn et al. (2015). In a follow-up study also using data from the Connecticut Longitudinal Study, Ferrer, Shaywitz, Holahan, Marchione, and Shaywitz (2010) sorted the sample into typical readers, poor readers whose performance stayed poor, and compensated poor readers whose performance improved. The coupling between IQ and reading comprehension was limited to the typical readers. They considered the lack of coupling between the development of IQ and reading comprehension for the poor readers whether compensated or not as evidence of the existence of reading disability.

Reynolds and Turek (2012) reported results from a latent change score modeling study that was more similar to Quinn et al. They studied the development of picture vocabulary as representing the construct of verbal comprehension, and reading comprehension at the third, fifth, and ninth grades. They also reported coupling from vocabulary to reading comprehension but not from reading comprehension to vocabulary.

We believe latent change score modeling of developmental data represents a way to look at the co-development of constructs that potentially might have an effect on the development of one another, as is the case for vocabulary and reading comprehension. Although stronger causal inferences can be made from true experimental designs, true experimental designs are limited to constructs that can be manipulated relatively easily over relatively short periods of time. A potential bridge exists between latent change score modeling and experimental studies by combining the designs. It is possible to use latent change score modeling to look for longer-term effects of interventions in the form of changes in the trajectory of development over time for an experimental group compared to a control group.

## Conclusions

In the present chapter, we provided a brief overview of the co-developmental relations between vocabulary knowledge and reading comprehension. The development of these two constructs is highly related, as exemplified in the observed correlations between the constructs and in the studies using structural equation modeling and latent change score modeling. The ways in which we measure vocabulary knowledge and reading comprehension appear to affect observed relations. We have highlighted the importance of considering morphological awareness as a supplement to vocabulary testing, and mentioned the limitations in using cloze-format and open-ended questions to measure reading comprehension. These limitations are addressed when multiple measures of either construct are utilized.

We believe latent change score modeling of developmental data to represent a way to look at the co-development of constructs that potentially might have an effect on the development

of one another, as is the case for vocabulary and reading comprehension. Although stronger causal inferences can be made from true experimental designs, true experimental designs are limited to constructs that can be manipulated relatively easily over relatively short periods of time. A potential bridge exists between latent change score modeling and experimental studies by combining the designs. It is possible to use latent change score modeling to look for longer-term effects of interventions in the form of changes in the trajectory of development over time for an experimental group compared to a control group.

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# 27

# THE EARLY STEPS IN BECOMING A WRITER

## Enabling participation in a literate world

*Rui A. Alves*

### Literacy

Humans are born free, or romantic minds like to think so. Still, that freedom can be immediately thwarted depending on the particular ill circumstances into which a child comes into being. This chapter is about a particular kind of freedom, the freedom that humans achieve when they become literate. Nurturing of this freedom starts in the womb, and its development can last a whole human life (Bazerman et al., 2018) and necessarily implies interplay among writers, communities, and culture (Graham, 2018). As is typical of freedoms, literacy is open-ended; it has no endpoint and allows for multiple trajectories and individually tailored literate achievements. As a freedom, literacy is best defined as a capability, in the sense conceived by Sen (1999, p. 75), that is, "a substantive freedom to achieve alternative functioning combinations". Functionings are the realization of capabilities, that is, the things individuals value doing or being, for instance, performing literate practices (e.g., reading, writing) or becoming literate. Literacy is a capability with a particular status, as it is key to securing a multitude of other functionings; that is, literacy is *fertile* as meant by Wolff and de Shalit (2007). The fertility of literacy and its vital role in present-day societies are well acknowledged by the wide agreement that it should become universal by 2030 (United Nations, 2015).

At the core of literacy lies a competence with a script (an external, permanent symbolic representation of a language) and the skills to access and use the wealth of currently available documentary resources (Olson, 2000). As seen in Figure 27.1, although the uses of a script by reading and writing lie at the core of literate practices, literacy is not restricted to the sole domains of reading and writing. As long as a domain makes use of a script and rests on the accumulation of documents and strategies to handle them, that domain needs to be considered a specialization of the literate mind. This is why we often hear about all sorts of literacy (e.g., health literacy, financial literacy, digital literacy, etc.), which collectively tend also to embrace the notion that to function properly in a given literate domain, individuals need to attain some level of competence in that domain. Clearly, this points to the fact that literate domains seem characterized by thresholds. Here, I consider two thresholds, those denoted by participation and change.

Becoming literate is a condition for participation in current highly bureaucratic and technological societies. Furthermore, mastering literacy is also an effective way to pursue changes in modern complex societies and institutions, which tend to be ruled by the written word, a prime

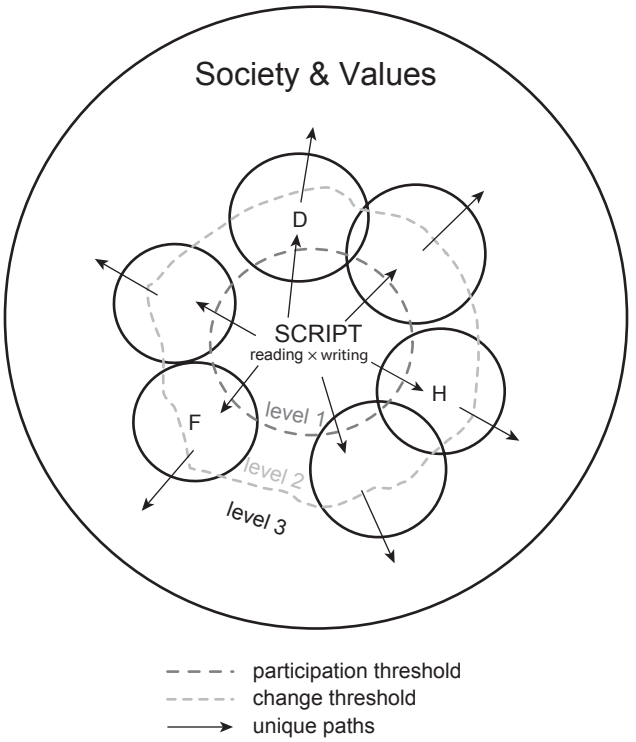



*Figure 27.1* A scheme depicting multiple literacy domains, literacy thresholds, and unique individual paths.

example of which is the rule of law. Consequently, acquiring fluency and expertise managing a script in a given domain points to two thresholds that individuals need to cross to become literate. The first threshold, that of participation, entails that functional literacy is attained (for a related discussion see Vvgvölgyi, Coldea, Dresler, Schrader, & Nuerk, 2016), and promoting such a standard is a main aim of basic, compulsory education. The second threshold, that of change, entails that an expert level in literacy is achieved; promoting such transformative capabilities is typically a focus of higher education. Clearly, I am not arguing that literacy is the only means for participating in and changing society and values, far from it. Only that in present-day literate societies, literacy can be a powerful tool to reach those goals. The existence of two thresholds is compatible with the scholarly discussion of Morais (2018) of literacy and democracy and his distinction of three levels in the literacy domain (viz. productive literacy, argumentative literacy, and creative literacy).

Patently, threshold crossing depends more on the existence of a literate culture and socio-economic factors than on the individual capacity to learn and use a script. Nevertheless, it is at the level of individuals that freedom is exercised, and fine-grained descriptions of predictable individual paths have been well researched and documented before. In this chapter, I focus on the early steps of becoming a writer, specifically on the development that allows crossing the participation threshold. For the sake of accuracy, I take the view that emerges from writing research, taking writing development in alphabetic writing systems as an analyzer of literacy in general. For the

core of the argument presented here, I believe that writing can be taken as a synonym of literacy, so that what is known about writing in particular can be expected to also characterize becoming literate in general.

## Writing development

It is a precondition for both humanity and language to be nurtured by another human and to be welcomed into a language community. Given these conditions, acquisition of a language can hardly be prevented (Bellugi, Poizner, & Klima, 1989; Liberman, 1996). Language is a necessary ground to install literacy, even if, from the perspective of the child, the relation between writing and language (either spoken or signed) is initially opaque. Interestingly, this seems to mirror the invention of writing systems, which have roots in accounting systems (Schmandt Besserat, 1996) and were not deliberate attempts to represent languages (Olson, 1994, 2016). As famously observed by Vygotsky (1935/1978), it takes a while for a child to discover the second-order symbolic nature of writing; that is, writing points to a language, which points to reality. Writing is thus intrinsically a metalinguistic activity and "largely responsible for bringing language into consciousness" (Olson, 1994, p. xxviii). As further noted by Tolchinsky (2009), literacy development can be conceived as the active construction of a particular domain of knowledge, that of the knowledge about a particular notation system, writing. As stated earlier, building of this knowledge domain is potentially a lifelong journey, which, to recap a famous distinction made by Luria (1929/1983), has a prehistory as well as a history. The history typically starts with a child going to school, and the requirements of that move were well synthesized by Graham (2006), who suggested that writing texts requests development across four domains: motivation, knowledge, skills, and self-regulation. Figure 27.2 depicts the main areas of writing development and some of the more frequently associated concepts. It does not intend to be an exhaustive map, as much as it is a simple scheme to structure the reading below (for a comprehensive account see Beard, Myhill, Riley, & Nystrand, 2009). The main assumptions of the scheme are denoted by the geometrical elements in the figure: the circle is the background, the square is the foundation, and the triangle is the control. The circle modulates the other areas, most of the square lies in long-term memory, and the triangle control typically operates in working memory.

### *Prehistory of writing*

It is no coincidence that we intuitively connect with the paintings and engravings found in Paleolithic caves. Probably at the core of such recognition lies the propensity of our species for action, meaning-making, and symbolic usages. While the distance from visual inscriptions to writing is enormous, it is critical to acknowledge, as did Luria (1929/1983) and Vygotsky (1935/1978), that some form of it lies also at the foundations of a child's first attempts to write. Luria and Vygotsky showed that gesture, language, and symbolic play are the early developmental precursors of writing inasmuch as they seem necessary to exercise a first-order symbolism that seems required to reach second-order symbolism. Learning to write thus compels the child to discover that the graphic marks one can produce can stand for one's own language and be used as a mnemonic tool to recover a fixed form of language, and do some thinking work with it. Discovering this is a remarkable feat for the child, one that gave rise to an extensive body of scientific inquiry (for scholarly reviews see Tolchinsky, 2003; and Treiman & Kessler, 2014), of which I can provide here only a few landmark examples.

One of the first distinctions children have to make in alphabetic writing systems is what counts as writing. If earlier, as shown by Luria (1929/1983), scribbles can count as writing, later,

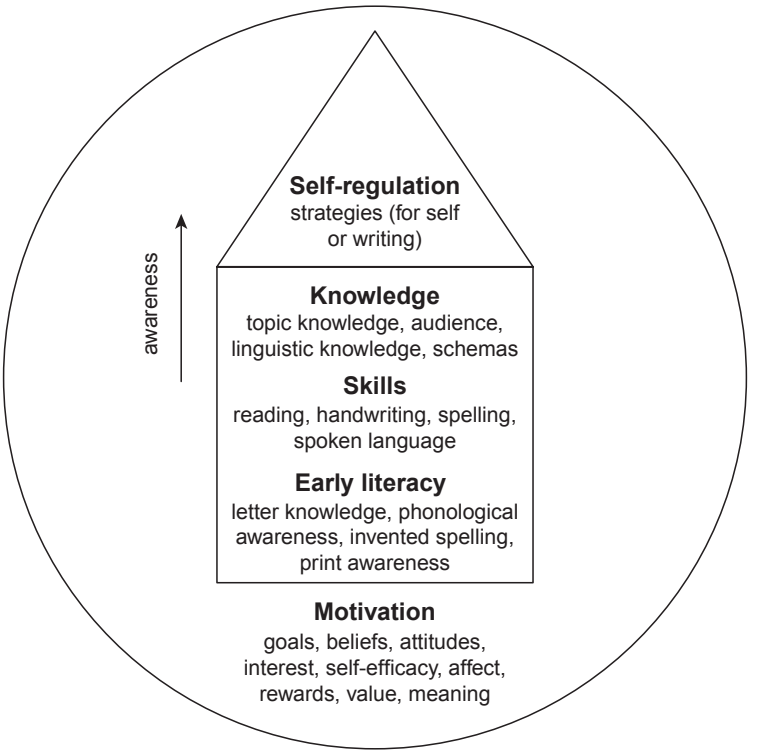



*Figure 27.2* Areas of literacy development.

as shown by Ferreiro (1988), a four-year-old will likely reject them and require the presence of a minimum amount of letter shaped forms and perhaps even some level of diversity across the letters to count the specimen as writing. Importantly, as noted by Tolchinsky (2009), the concept of writing (i.e., leaving permanent traces) is understood earlier than that of reading. In literate societies it is a common observation that preschoolers make plentiful attempts to write (invented spellings), long before they are able to read. As cogently argued by Olson (1996, 2016), those attempts are responsible for bringing language into awareness and allow for the development of metalinguistic concepts such as words and phonemes.

In literate environments an initial step that most children take informally is to notice that writing exists out there in the world, that it can take multiple forms and is given many uses, and that writing is a curious object ruled by a huge number of conventions. In other words, the child has to gain what has been called print awareness (Paratore, Cassano, & Schickedanz, 2011; Sulzby & Teale, 1991). What is a book, a note, an e-mail? Why do children write to Santa Claus? In a page, where should one start reading? What are punctuation marks? Obviously, this list could go on and on, just for the sake of remembering the position of children, as they start to build a literacy domain knowledge. Nevertheless, one thing that so many questions should not elude is that a child can only pose those questions if living in a literate environment; if not, the child is at a disadvantage.

To read an alphabetic script, a crucial discovery that children have to make is that of the so-called alphabetic principle; that is, graphemes stand for phonemes. As extensively demonstrated, this discovery relies heavily on phonological awareness and letter names (Foulin, 2005; Share,

1995; Treiman, 2000). It would almost go without saying that children need a literate community to explicitly teach them how to make this discovery (Castles, Rastle, & Nation, 2018). One need only to look for adult illiterate statistics to be convinced of such a sine qua non condition.

Clearly, there is much more to the prehistory of writing than it is possible to point to in this review. Actually, a case could be made that the whole of language development, as addressed in this handbook, is important to build writing. Also, highly relevant is the consideration of the characteristics of the languages and scripts that children are being exposed to and taught, respectively. In that regard, the field of early literacy needs to move away, as argued by Share (2008), from the anglocentricities that dominate the research and practice of literacy, and adopt a truly informed cross-linguistic stance. Some examples of such efforts are already available (Caravolas et al., 2012; Caravolas, Lervåg, Defior, Seidlová Málková, & Hulme, 2013; Moll et al., 2014; Seymour, Aro, & Erskine, 2003), but admittedly this seems a task for many research generations.

## *Motivation to write*

From the very outset, literacy needs to be rewarding, valued, and meaningful so that it can be sustained. From the toddler who finds immediate gratification in using a crayon to leave red traces on the walls of the family's living room to the writer who cannot live without writing, there is a continuum that is in part justified by motivation and meaning-making (Ariely, 2016; Kellogg, 1994). The struggle with motivation to write is that it is fragile (Alves & Limpo, 2015a) and might vanish easily. Complexity, effortfulness, and the social nature of writing account for the difficulty in sustaining motivation to write.

The cognitive tradition of writing research, tracing back to the pioneering studies of Emig (1971) and Hayes and Flower (1980), is responsible for foregrounding a view of writing as an inherently complex and demanding activity. Such complexity is owed to the interplay of a considerable number of recursive cognitive processes and to the interactive nature of writing, which far from depending solely on the writer involves interactions with writing tools, the emerging text, and potentially the whole social network in which writing happens (Flower & Hayes, 1980). Perhaps one of the best examples of such complexity is offered by the individual-environment writing model proposed by Hayes (1996). In this model, the environment is eminently social, comprising both the audience and the collaborators, and including also the text so far and the mediums used to compose it. The recent writers-within-community model of writing (Graham, 2018) shows even more forcefully how writing is inherently social and strongly shaped by everything that lies outside of the writer's skin. The individual in Hayes' model is depicted as a conglomerate of motivation (comprising goals, predispositions, beliefs and attitudes, and cost/benefit estimates), long-term memory (comprising task schemas, topic knowledge, audience knowledge, linguistic knowledge, and genre knowledge), cognitive processes (comprising text interpretation, reflection, and text production), and working memory playing the pivot role (comprising phonological memory, a visual/spatial sketchpad, and semantic memory). Noticeably, the elements in Hayes' model are themselves collections of a huge number of constituent sub-processes that cognitive accounts of writing explore thoroughly. This large number of system elements shows well the arduous task that the prospective writer faces. Of course, not all elements are equally hard to master, but the sheer number of things to handle can become discouraging. Furthermore, difficulties in a single element might be sufficient to disrupt the whole endeavor. The complexity of writing also accounts for the need for not only extensive practice of writing nuts and bolts, but also deliberate practice (Ericsson & Lehmann, 1996) of those generative aspects of writing that need to resist automatization (McCutchen, 1988), so that expertise in writing can truly be achieved (Kellogg, 2006, 2008).

Writing might never cease to be effortful, from mastering handwriting to continuously challenging oneself through deliberate practice to improve performance (Kellogg, 2006). As incisively noticed by Bereiter and Scardamalia (1987), writing does not get easier with expertise; instead, expert writers choose to tackle ever tougher problems. Perhaps the most elegant experimental demonstration of the effortful nature of cognitive processes in writing comes from the programmatic research of Kellogg (1987a, 1987b, 1988, 1990) that assessed cognitive effort during text composition, measured as the interference in secondary-task reaction times to random auditory probes, as compared to single-task reaction times. Consistently, Kellogg showed that cognitive processes in writing are effortful and only equivalent to those engaged, for instance, by experts playing chess; as vividly put by Kellogg (1994, p. 17), writing "is the mental equivalent to digging ditches". Seen this way, one can have a good appreciation of the strength of will that a child needs for learning to write and, critically, to sustain and improve writing over the years.

Writing is inherently social; we write to be read. Writing is always situated within a community (Graham, 2018), which as acutely noted by Hayes (1996, p. 5) "provides the words, images and forms from which we fashion text". Communities are also invaluable for providing all sorts of material supports that make writing possible and are critical in nurturing and challenging its development. Nurturing is decisively accomplished by reward and affect; challenging is provided by feedback from writing collaborators, and from goals set forward. Unfortunately, rewards, affect, feedback, and goals are not guaranteed, tend to be uncertain, and can be of the wrong kind. Such a constellation is likely to arrest writing motivation.

Writing necessitates a particular affective environment, one that is positively charged, well-scaffolded and that values literacy. Camacho and Alves (2017) developed a parental intervention set out to establish such an environment during 10 training weeks. They worked with parents of seven-year-olds and evaluated children's texts at pretest and posttest. They found that children whose parents were in the intervention group improved some transcription skills and wrote better texts than children on the waiting list. Writing also necessitates particular constellations of goals, beliefs, attitudes, and interests. Fine-grained sketches of such constellations are not yet available, as motivation constructs in writing have been under-researched (Alves, 2012). Nevertheless, the importance of some elements is already established; for instance, self-efficacy stands as the most researched motivational construct in writing and is a consistent predictor of writing performance (Bruning, Dempsey, Kauffman, McKim, & Zumbrunn, 2013; Graham, Kiuhara, Harris, & Fishman, 2017; Pajares, 2003). Not only are beliefs about self-competence important, but beliefs about writing itself (ascribing value to writing, Boscolo, 2012; Shell, Colvin, & Bruning, 1995) and about writing ability also seem to play crucial roles in writing development (Bruning & Horn, 2000). The latter are commonly referred as implicit theories or mindsets (Dweck, 1986, 2006) and have been studied in relation to writing by Limpo and Alves (2014). They showed that students who believed that writing skill is incremental benefited the most from a Self-Regulated Strategy Development writing intervention (SRSD, Harris & Graham, 1996, 2009) as compared to students who believed writing ability to be fixed.

Another important aspect to keep in mind about motivation to write is that it is itself subject to development. Popularly, motivation tends to be thought of as an on/off switch: either the student is motivated or not. Such a view is misleading as it hides what might be best characterized as a gradient in which qualitatively different phases are discernible. Perhaps the motivational concept that most clearly shows such a predictable path is that of interest, which as suggested by Hidi and Renninger (2006) typically goes through four phases (not necessarily in a straightforward manner). In writing, interest is the cognitive-affective result of the interaction between the writer and writing (Lipstein & Renninger, 2007; Nolen, 2007), and develops from triggered situational interest (phase 1), to maintained situational interest (phase 2), to emerging individual

interest (phase 3), to well-developed individual interest (phase 4). Important to notice in this sequence is the movement from contextual fortuity to stable individuality and its reliance on social support (Hidi & Renninger, 2006).

Together, the complex, effortful, and social nature of writing synthesizes well the potential lifelong quest of those engaged in improving writing. The only assurance in that quest seems to be that writing can be consistently hard work, as both its complexity and its social nature tend to bring a great level of uncertainty to the task. Complexity accounts for the relative unpredictability of the final written product, with many writers describing the process of writing as one of discovery (Galbraith, 2009). Furthermore, the communities' responses to and rewards for the end product are uncertain and for the most part outside of the writer's control. This bleak scenario seems further aggravated in the current fast-paced world, wherein innumerable immediate pleasant options compete with setting time aside for writing. Within such a context, it seems likely that motivation to write might arrest prematurely. Sure enough, it might not even be desirable that everyone becomes an expert, transformative writer, but as a minimum the community needs to guarantee that motivation to write fuels the necessary development to cross the aforementioned participation threshold.

## *Literate knowledge*

In a sense, becoming literate is only possible because individuals have the capacity to build and store internally or externally literate knowledge, that is, knowledge about the forms, functions, and uses of literacy. Internally, that knowledge is stored in long-term memory, as acknowledged by virtually every cognitive model of writing. As mentioned above, Hayes (1996) characterized writing knowledge stored in long-term memory as comprising task schemas, topic knowledge, audience knowledge, linguistic knowledge, and genre knowledge. These specific forms of writing knowledge are of course built from the child's experiences with writing, but as noted by Graham (2018) they have other important sources, namely, oral language, listening skills, reading, and writing communities. It is very important to keep in mind these sources, as literate knowledge seems, in essence, distributed. As conspicuously shown by present-day digital worlds, knowledge is far from being stored only in the writer's mind; actually, it even seems that it is escaping from it.

As children use writing, they typically develop schemas for how to carry out writing tasks. As noted by Hayes (1996), schemas play a supervisory role (see also Shallice & Burgess, 1996) and include information on how to perform a given writing task: its goals, the processes needed to do the task, how processes are used and sequenced, and some criteria to evaluate success in the task. Schemas in writing are idiosyncratic and multiple, and can vary widely in scope, for instance, from a schema to correct a spelling mistake to one for writing a book.

One typically assumes that writing something presupposes knowledge about the topic being covered; indeed, this assumption is a basis for the extensive use of writing as an evaluation tool in schools. Surprisingly, empirical research showing that better writers know more about their topic is limited (Graham, 2006; Olinghouse, Graham, & Gillespie, 2015). Nevertheless, the available findings agree well with this common assumption. Recently, Olinghouse et al. (2015) found that topic knowledge accounted for unique variance in the text quality of 5th graders writing story, persuasive, and informational texts.

While a representation of an imagined reader might enter the mental problem space of producing a text relatively late in the acquisition of writing expertise (see Kellogg, 2006, 2008), it is possible to observe that even children can show audience awareness and adapt a piece of writing to the imagined perspective of a reader (Lee, Karmiloff-Smith, Cameron, & Dodsworth,

1998). Holliway (2004) showed that 5th and 9th graders could use the strategy "reading-as-a-reader" to better suit descriptive texts to the needs of their readers. Building a representation of a reader, and specifically of how a reader might interpret the text being written, seems to be a cognitively demanding task (Holliway & McCutchen, 2004; McCutchen, 2000). Furthermore, for this reader representation to be effective in shaping text, Kellogg (2008) suggests that it needs to be manipulated in working memory jointly with the author and the text representations; this three-way interaction seems a feat available only to expert writers.

The linguistic knowledge alluded to in Hayes' model (1996) is comprehensively described by Graham's remark (2018) on oral language as being an essential source of knowledge for writing, thus including phonological, semantic, syntactic, and pragmatic knowledge. Clearly, good writers need to know words, master their meanings and combinations, and skillfully use them to be felicitous. Furthermore, children writers also need to learn about discourse types and the genres commonly used in their communities. What seems distinct about linguistic knowledge is that it comprises levels that seem to require independent skill learning and practice (Alves & Limpo, 2015a). Berninger and collaborators have systematically shown not only interindividual differences across levels of language production (Abbott & Berninger, 1993), but also intraindividual differences (Berninger, Mizokawa, Bragg, & Cartwright, 1994; Whitaker, Berninger, Johnston, & Swanson, 1994). Such findings point to the need for writing instruction to consider a range of language levels, to provide effective teaching and practice at each level, and to be tailored to the language strengths and weaknesses of each learner.

While genre distinction can be noticed early on, the production of full-fledged good exemplars takes time to learn and seems dependent upon skillful teaching. The studies of Berman and Katzenberger (2004) and Berman and Nir-Sagiv (2007) show the progress in narrative and expository writings from child to adult writers. Similarly, Beers and Nagy (2009, 2011) showed how syntactic structures need to be accommodated depending on the text genre being produced. Using the tenets of the SRSD model (Harris & Graham, 1996, 2009), Limpo and Alves (2013a) developed and tested a sentence-combining instruction and a planning strategy instruction, which they plotted against standard writing instruction. As expected, the experimental groups outperformed the control, and notably the sentence-combining group showed stronger gains at the word and sentence levels, whereas the planning group showed stronger gains at the discourse level. Recently, Limpo and Alves (2018) compared SRSD only, SRSD + Transcription, and standard writing instruction. They found an incremental effect of the multicomponent intervention, which was particularly effective for the poorer writers.

## *Skills in writing*

Skills and strategies are goal-directed actions that seem to fall along a continuum of automaticity and intentionality (Alexander, Graham, & Harris, 1998), with the former being automatic, effortless, and involuntary, whereas the latter are controlled, effortful, and intentional. While, early on, the skills to be mastered require controlled attention, through practice they run into automaticity. A distinctive feature of writing is that some strategies seem to resist automatization and persist in being deliberate, effortful, and conscious (McCutchen, 1988; Torrance & Jeffery, 1999). As shown up till now, much of writing is strategic, indeed many scholarly accounts depict it as inherently effortful, problem solving, and goal directed (Bazerman, 2013; Graham, 2006; Hayes & Flower, 1986; Kellogg, 1994). Here, I would like to claim that strategy is enabled by automatizing the skills in writing. For the most part, skills in writing are related to the language component in the system, be it spoken or written. Translating ideas into spoken language and giving it a syntax becomes automatic early in childhood. Somewhat later, handwriting, spelling,

and reading can also gain automaticity through schooling, provided that they receive extended and consistent practice.

As handwriting and spelling need to become closely intertwined in writing, their integration is often called transcription (Berninger & Swanson, 1994), and it is well established that transcription skills exert a considerable toll in early phases of writing development (Graham & Harris, 2000). This is shown by removing transcription skills through composing by dictation, which leads to increased text quality in both young and struggling writers (Bereiter & Scardamalia, 1987; De La Paz & Graham, 1997; Graham, 1990; Reece & Cumming, 1996). Noticeably, transcription skills typically account for a sizeable amount of variance in writing fluency and text quality (Graham, Berninger, Abbott, Abbott, & Whitaker, 1997) and in young students also show a direct contribution to text quality (Limpo & Alves, 2013b). Furthermore, training transcription skills early on, that is, in 1st and 2nd graders, improve text quality (Alves et al., 2016; Berninger et al., 1997; Graham, Harris, & Fink, 2000; Graham, Harris, & Fink-Chorzempa, 2002; Jones & Christensen, 1999). Recent meta-analyses on handwriting (Santangelo & Graham, 2016) and spelling instruction (Graham & Santangelo, 2014), while confirming many positive impacts on literacy development, also allowed differentiating the aspects of literacy that are likely to be impacted by handwriting (viz., handwriting legibility, writing fluency, text length, and text quality) or spelling (viz., spelling accuracy, spelling when writing, phonological awareness, and reading skills).

Transcription skills are an essential part of writing; actually, it is the aspect that is most easily observed when seeing someone write a text. While many have observed writing, Kaufer, Hayes, and Flower (1986) have made the pregnant observation that writers usually transcribe using sentence parts, averaging about nine words, then pause production for brief moments (typically a few seconds) and then proceed with transcribing another sentence part, pause again, and so on and so forth. These sentence parts were later called bursts of written language (Chenoweth & Hayes, 2001). They were initially studied in adults and more recently also in children (Alves, Branco, Castro, & Olive, 2012). Kaufer et al. (1986) found that expert writers as compared to college students composed using longer bursts. Chenoweth and Hayes (2001) found that bursts are longer in first language than in second language. Chenoweth and Hayes (2003) showed that bursts are temporarily stored in verbal working memory as articulatory suppression reduced burst length considerably. Hayes and Chenoweth (2007) located the source of bursting in the process of translating ideas into new language. Alves, Castro, Sousa, and Strömqvist (2007) showed that adults with high typing skill had longer bursts. Alves (2013) manipulated transcription skill in both handwriting and typing, and as expected the experimental conditions high in transcription skill showed longer bursts.

Considered together, studies with adult writers have consistently shown that bursts seem to be dependent on translating and transcribing processes involved in writing. This was further confirmed in studies with developing writers. Alves et al. (2012) found that 4th graders of high handwriting skill used longer bursts than those of low handwriting skill. Connelly, Dockrell, Walter, and Critten (2012) found that children with specific language impairment had shorter bursts than age-matched controls, but similar to language-matched controls. Testing the idea that bursts might increase throughout schooling, thus mirroring improved language ability and handwriting skills, Alves and Limpo (2015b) conducted a cross-sectional study with 249 children from Grades 2–7, writing a narrative text and an opinion essay. Across both genres, they found a steady increase in burst length from about two words in Grade 2 to about six words in Grade 7. Using regression analyses, they also found handwriting to be a strong contributor to burst length across genres. In a subsequent intervention study, Alves et al. (2016) tested the nature of the relation between transcription skills and burst length. They randomly assigned

2nd graders to handwriting, spelling, or keyboarding interventions and provided 20 hours of training on the assigned transcription skill. They found that children in the handwriting group showed higher handwriting fluency, longer bursts, shorter pauses, longer texts, and overall better stories than keyboarding students. This intervention study was the first to hint at a causal relation between handwriting skill and burst length. Recently, Limpo and Alves (2017) further established the mediating role that language bursts play between transcription skills and writing performance. What is clear from the reviewed research on bursts is that bursts tend toward automaticity; that is, with improved language ability and transcription skill, bursts tend to increase and progress uninterruptedly until a chunk of information is transferred from the mind onto paper, thus becoming a major source of writing fluency and efficiency.

Along with handwriting and spelling, a major literate skill on which writing also relies is reading. As suggestively put by Ehri (2000), spelling and reading are closely related, but they are not the same; they are like two sides of the same coin. Developmentally, they both rely on building knowledge about the alphabetic system and knowledge about the spelling of specific words, but as further noticed by Ehri, the two use orthographic knowledge stored in memory asymmetrically, with spelling exerting heavier demands on memory than reading does. Reading development, particularly in alphabetic writing systems, has been extensively researched, and a predictable path of phases in learning to read/spell is known and well agreed across many developmental theories (for a review see Ehri, 2005a). Currently, perhaps the most influential developmental model of learning to read is the one proposed by Ehri (1999, 2005a, 2005b) that distinguishes four main phases that were named after the child's mastery of the alphabetic principle and the predominant kind of connections that bond written words and their pronunciations in memory. As alluded earlier, the pre-alphabetic child is not aware of the relation between written words and their spoken counterparts, and thus "reads" by relying on visual or contextual cues that accompany print. The partial alphabetic child knows some letters and corresponding sounds and uses them to start reading some words. The full alphabetic child has mastered the alphabetic principle and knows of all connections between graphemes and phonemes. The consolidated alphabetic child reads every word by sight, relying on syllables and morphemes; she or he reads whole words, and reading has become fully automatic. It is well established that the pace of development across the mentioned phases can vary widely according to the availability, consistency, and granularity of the correspondences between phonology and orthography (Ziegler & Goswami, 2005). For instance, it takes about three years of instruction for an English child to reach the same level of reading accuracy that a German child reaches after one year (Frith, Wimmer, & Landerl, 1998). The differing characteristics of orthographies ought also to have an impact on text production, particularly while reading, spelling, and handwriting are still being mastered.

Taken together, skills in writing show that the language part in writing is most amenable to becoming automatic. Through consistent practice, handwriting, spelling, and reading can become automatic (Cohen, Servan-Schreiber, & McClelland, 1992), that is, fast, requiring little attention, involuntary, non-interfering, and thus releasing working memory capacity that can be used for thinking processes in writing (McCutchen, 1996). As wisely argued by McCutchen (1988), gaining expertise in writing is not only a matter of becoming automatic, but foremost a matter of rendering language penetrable to metacognitive control and allowing for interactions across writing subprocesses, and that is a matter of using strategies and self-regulation.

## *Self-regulation in writing*

Self-regulation in writing refers to a set of purposeful thoughts, feelings, and actions that writers commonly use (Zimmerman & Risemberg, 1997) to control the environment (physical or

social; e.g., writing in a specific setting, selecting a writing tutor), behavior (e.g., keeping a record of pages written daily, rewarding oneself for a writing outcome), or the self (e.g., setting goals, evaluating one's writing). One striking observation about self-regulation in writing is that it is quite common among expert writers (Gourevitch, 2006; Graham & Harris, 2000), whereas children seldom do it (Limpo, Alves, & Fidalgo, 2014; McCutchen, 1988). Several reasons account for the limited presence of self-regulation in children, among them the possibility that no one has shown children how to do it; the demanding and effortful nature of strategies which need to be juggled with the high cognitive cost of transcription, which in children seems enough to exhaust working memory capacity (Bourdin & Fayol, 1994; McCutchen, 1996; Olive & Kellogg, 2002); and also the inherent metacognitive nature of self-regulation (Alexander et al., 1998) that relies on brain structures that mature relatively late in development (Berninger & Richards, 2002). Noticeably, self-regulation of writing seems to be the slow result of writers' experiences with what works for them, what makes writing happen, and what makes it rewarding and effective. In other words, strategies and self-regulation are learned. Teaching self-regulation strategies (e.g., self-monitoring, self-instruction) and writing strategies (e.g., the TREE strategy for an opinion essay: Topic, Reasons, Explanations, Ending; Harris, Graham, Mason, Friedlander, 2008) is among the most effective tools to improve children's writing (Glaser & Brunstein, 2007; Graham, McKeown, Kiuhara, & Harris, 2012; Graham & Perin, 2007; Santangelo, Harris, & Graham, 2016). There is a huge number of self-regulation strategies; for instance, Graham (2006) comprehensively listed 16, while noting that the bulk of beneficial empirical evidence pointed to the effectiveness of planning and revising and that cumulative effectiveness should be expected from the combination of multiple self-regulation strategies.

Currently, SRSD (Harris & Graham, 2009, 2016) stands as the most comprehensive approach to writing instruction, and it also has the widest evidence-based support available (more than 100 studies). SRSD has been under development for about 40 years now (Graham & Harris, 2009) and has helped to improve the writing of children with or without learning disabilities, across grades (2–12), and in a variety of genres (including narrative, argumentative, and expository texts). The powerfulness of SRSD seems to be owed to the integrative work that is performed around instruction on strategies. Strategies are not just explicitly given, but are integrated in a sequence of loose stages that typically proceed from development of the background knowledge necessary for strategy use, to discussion of the strategy, to teacher modeling of the strategy, to student memorization of the strategy, to teachers' support of students' practice, with scaffolds progressively removed, along with encouragement of independent practice and care for maintenance and generalization (Harris & Graham, 2009).

As children gain experience with writing, learn writing strategies and strategies to regulate the self during writing, become aware of the final written texts, and feel rewarded for writing, they will likely value writing more, get ever more interested in it, and begin to derive a sense of self-efficacy for doing it. One important aspect of this early sense of self-efficacy is that it is likely to be built around a mastery of transcription skills (e.g., being able to spell correctly, to write fast, to write neatly) as these, more than planning or revising, are early salient features of writing for children. In fact, Limpo and Alves (2013b), using multiple-group structural equation modeling on a comprehensive set of writing measures, including transcription, planning, revising, text generation, and self-efficacy, found that in two grade groups (4–6 and 7–9) transcription contributed significantly to self-efficacy, whereas planning or revising did not. Transcription might be a source of writing self-efficacy with a narrow half-life, but it might set the stage for high-level processes in writing, such as planning and revising, by both allowing cognitive capacity and providing a secure base on which to experiment with more demanding aspects

of writing. Ultimately, self-regulation seems mandatory to make these high-level processes in writing effective.

## How to make writing easy?

Broadly put, the challenge that writing poses to the child who already knows "how to write" (i.e., encode and decode written language) is that of "what to write" (i.e., finding content to write), and this, as insightfully noticed by Bereiter and Scardamalia (1987), implies moving from a dialogical mode of language production (speech) to a monological mode of text production. For the typical 8-year-old, speaking is easy; the shared context and the dialogue partners provide plenty of cues to prompt and sustain language production. A lot is shared by simply standing in the same context, and conversation can flow with mutual understanding relying mostly on tacit shared context, with immediate possibilities for feedback and clarification. In conversations, dialogue partners and context support language production. Comparatively, in text production, partners are typically absent, and their position changes radically from that of being conversational partners to that of being readers; also, context is not shared and needs to be construed through writing. Thus, producing language in this novel monological situation poses challenges to the child. One of those challenges is to become fully aware of the new communicative context created by writing; another, more easily tractable, is that of finding something to write in the absence of external aids. Described this way, writing is a truly mental challenge to the child, as this new mode of language production relies heavily on the self and on its ability to build a mental representation of the writing task and to manage content knowledge and discourse knowledge. As well established by Bereiter and Scardamalia (1987), these three elements are the minimum that the self needs to regulate and build a first effective strategy to accomplish writing.

Typically for the child, writing starts with an assignment, some external request to produce written language (of which the child builds a representation). In the face of that request, the child searches memory for relevant content and discourse knowledges that are retrieved and coded into written form. In essence, writing is reduced by the child to a form of searching memory for some knowledge and telling others about it; thus, Bereiter and Scardamalia felicitously labeled this composing strategy as knowledge telling. Notice that this strategy is not distinct from cueing memory to speak, but crucially with the added constraint of respecting some standards for writing. However, as observed before, the nature of the cues is rather distinct in speaking and in writing; while in speaking they can be waived, relying on the environment, in writing, for the most part, they have to be generated within the mind. This is true at least until some text emerges, which then can also be used to cue related content in memory. The child beginning to write has to move from conversation to knowledge telling, and as cogently put by Bereiter and Scardamalia, for most this is an easy path – so easy that provided that good content and discourse knowledges are available and some judgments of appropriateness are made, writing can be made quite effective, and good texts be written, through knowledge telling (Bereiter & Scardamalia, 1987). Actually, surely for the majority, including university students and professionals who routinely use writing, writing can become easy and be used in a quite functional and effective manner. Such easiness in the domain of writing is a sign that the first literacy threshold, that of participation, has been crossed.

Needless to say, writing development does not stop with knowledge telling (even if a majority of literate persons may arrest at this point), but as stated earlier, the aim of this chapter was just to cover the first steps in becoming a writer. Nevertheless, it is no secret that if we wish to promote growth away from knowledge telling, one needs to disrupt it, create problems in

both the content and rhetorical spaces, and bring a truly reflexive stance to the text production domain (Bereiter & Scardamalia, 1987).

## Conclusion

Becoming literate entails crossing two thresholds: the first allows fluency and participation, and the second allows expertise and change. In this chapter, writing was taken as an analyzer of literacy development, and the conditions for crossing the participation threshold were reviewed. As remarked by Graham (2006), development of writing stands on a four-legged chair: motivation to write, knowledge, skills, and self-regulation. Breakup or frailty in any of the legs risks compromising and arresting writing development.

Perhaps one of the most vulnerable legs is motivation, which is critical for initiating and sustaining writing. Nevertheless, if care for motivation to write is in place early on and has a focus on creating a positive, nurturing, and adequately demanding atmosphere in which writing can be cultivated, the chances are that motivation to write will become intrinsic and develop into a self-sustained and self-reinforcing cycle (with the individual creating their own challenges and rewards), and thus writing can be sustained and become a valuable meaning-making activity.

While present-day digital societies seem characterized by externalization and collective distribution of literate knowledge (for instance, distribution of expertise among team members), it seems important that writers can still store in their long-term memories, if not the actual knowledge, then the ways through which knowledge can be efficiently retrieved and implemented. Examples of knowledge vital for writing are writing schemas, topic knowledge, audience knowledge, and linguistic knowledge. While it is nowadays virtually impossible for any individual to store internally all available knowledge in a given domain, this should be no excuse for downplaying the value of memory, particularly procedural memory, in allowing for expert performance in a given domain. While not all knowledge can be remitted to long-term memory, sometimes having it readily available internally might be the most efficient way to use needed knowledge.

Transcription skills are quite susceptible to becoming automatic in writing, and in this way releasing cognitive capacity, promoting fluency in writing, and enabling a strategic mode of functioning. An important index of fluency in writing seems to be burst length, which in children was shown to mediate the relation between transcription skills and writing performance (Limpo & Alves, 2017) and to be causally dependent on the automatization of handwriting (Alves et al., 2016), as training in handwriting leads to increased burst length. Reaching automaticity in reading also seems valuable in favoring fluency in writing and, jointly with burst behavior, also seems critical to enable strategic behavior in writing.

As a demanding activity from the very beginning, writing prompts the child to regulate the several demands posed by the task and to become self-regulated. This self-regulation of writing can be hugely scaffolded by strategic writing instruction (Santangelo et al., 2016), of which a prime example is the SRSD model (Harris & Graham, 2016). But even with minimal instructional support, children typically show a first emergent strategy that was characterized by Bereiter and Scardamalia (1987) as knowledge telling, which, supported by spoken language abilities, relies on constructing content and discourse probes that cue long-term memory for associated knowledge, which is then written down as it is retrieved and formulated. Through knowledge telling, writing can be made easy, but that comes with a cost, that of preventing reflection and a truly strategic and self-regulatory stance in writing, which ultimately hold the key to expertise in writing. If one aims at transformative actions of reality, then literacy development should not get stuck on fluency.

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# GLOSSARY

**Adaptation (speech production):** Production of word with modification of the target form to fit a pattern (template) in the child's existing vocal repertoire. For example, the child may have the template "Consonant-Vowel-Consonant-i" <CVCi>, which fits words in the lexicon such as "Mommy," "Daddy," and "bunny." Adaptation involves shaping other words to fit this template, e.g., by using the form "botty" for "bottle." See also ***Template***.

**Adult-directed speech:** Speech directed to an adult that usually has a lower fundamental frequency and less prosodic variation than child-directed speech.

**Affect:** Emotional valence, which can be expressed in the speech signal.

**Affricate:** A consonant that begins with a stop and closes with a fricative (e.g., the onset of "chair").

**Agent:** The cause or the initiator of an event. Typically animate.

**Alphabetic principle:** The idea that letters stand for units of spoken language.

**Amplification:** The process of increasing the volume of sound. For people with hearing loss, fitting devices such as hearing aids can help with amplification.

**Animacy:** A grammatical feature that identifies whether a word refers to a living, volitional referent.

**Argument:** An expression that completes the meaning of a predicate. Usually refers to the subject and the object(s) of the verb.

**Argument structure:** The configuration of arguments with respect to a predicate in terms of their types and number.

**Articulation impairment:** A type of speech sound disorder where children misarticulate particular sounds in words. A common example is the interdental lisp where an /s/ sound is produced with the tongue between the teeth. Children with articulation impairment do not have difficulties moving face and tongue muscles, but have difficulty producing particular sounds. Compare ***Phonological impairment***.

**Articulatory complexity:** The complexity of motor movements required to produce specific words. Polysyllabic words have greater articulatory complexity than monosyllabic words.

**Articulatory filter:** The hypothesis that speech input that is similar to (some of) an infant's own vocalizations will create a "pop-out effect," similar to the cocktail-party effect in adults.

**Artificial grammar:** A made-up grammar composed of sequences of symbols (e.g., sequences of letters or novel words) and a set of rules for how the symbols may be combined. The rules may resemble a fragment of a grammatical structure found in natural language. Artificial grammars are helpful in minimizing the effects of pre-existing knowledge and gaining experimental control.

**Audibility:** The amount of sound signal above the hearing threshold of the listener. Aided audibility is the amount of an amplified signal above the hearing threshold of the person using amplification (e.g., a hearing aid or a cochlear implant).

**Audience knowledge:** A speaker's or writer's knowledge about potential addressees (e.g., their characteristics, needs, goals, or beliefs). Audience knowledge can impact the formulation of the message directed to the addressees. Thus, a speaker or a writer may adapt a message to produce a certain rhetorical effect on an audience or to make it easily understood by children. Audience knowledge allows a speaker or writer to be felicitous or to better attain a number of rhetorical goals that an addresser aims to accomplish.

**Autism spectrum disorder:** A neurodevelopmental disorder characterized by persistent deficits in social communication and social interaction, coupled with restricted and repetitive patterns of behavior, interests, or activities.

**Base-rate frequency:** The number of times a token occurs in the input.

**Bayesian model:** A probabilistic statistical inference model using graphs of random variables.

**Benefactive:** A participant in an event that receives some benefit out of it.

**Bottom-up:** A learning process in which knowledge is acquired from low-level input and does not require existing knowledge. For example, knowledge of segmental or suprasegmental categories can be learned from patterns in speech input and does not require lexical knowledge (i.e., understanding of the speaker's message). Compare ***Top-down***.

**Bursts of written language:** A number of words written in quick succession. Written language is typically produced intermittently. The overt execution of the written message is frequently interrupted by long production pauses (often longer than 2 seconds), during which a number of mental processes engaged in text production are active. Length of bursts is commonly measured in words. Length of bursts is influenced by a number of factors and tends to increase as language expertise develops.

**Canonical babbling:** The production of consonant-vowel (CV) syllables that roughly reproduce the temporal characteristics of adult speech.

**Child-directed speech/action:** Speech or action directed to infants or young children that contains exaggerated features, such as high pitch, elongated vowels, and fluctuating prosody (for speech) and pronounced and repetitive movement (for actions). See also ***Adult-directed speech***.

**Childhood dysarthria:** A motor speech sound disorder that has a neurological basis. Childhood dysarthria impacts children's ability to physically produce the speech sounds required to say words. See also ***Articulation impairment*** and ***Phonological impairment***.

**Closed-class words:** Words that fulfill relational functions and can be defined primarily with respect to the grammar of a language (e.g., determiners, prepositions, pronouns, conjunctions). These are also known as function words. New closed-class words are seldom added to a language.

**Cochlear implant (CI):** A surgically implanted electronic device that bypasses the damaged parts of the inner ear to stimulate the hearing nerve directly.

**Coda:** The consonant that closes a syllable. For example, the t is the coda in "boat." The coda may include more than one consonant, depending on the language.

**Codeswitching:** The use of phonemes, words, or grammatical patterns from more than one language during the same sentence/utterance or stretch of conversation. Also known as code-mixing.

**Computational model:** A mathematical or algorithmic model used and studied through computer simulations.

**Connectionist model:** Models of mental phenomena often described as interconnected networks of simple uniform units. See also ***Neural network***.

**Consonant harmony:** The process of adapting a word with different consonants by modifying one to match the other (e.g., "goggy" for "doggy").

**Consonant variegation:** A difference of place and/or manner of articulation across consonants within a single lexical unit (e.g., "cat" or "dog" but not "mama" or "baby"). This is the single biggest phonological challenge in word production for most infants.

**Constructive play:** Play involving manipulation of the spatial properties of one or more objects, such as building with blocks, inserting shapes into shape sorters, or interconnecting puzzle pieces.

**Context-limited word use:** Word production that is primed by the situation. For example, an infant only uses a given word in a meal-time context.

**Contingent responsiveness (contingency):** Verbal utterances that follow on the infant's behavior and are relevant to it, mostly occurring within a 3-second window (e.g., saying "truck" when the infant touches a toy truck).

**Coronals:** Consonants produced with the tip or front part of the tongue touching or approaching the palate, or roof, of the mouth.

**Cross-situational word learning:** The way in which words are learned gradually across several ambiguous trials or situations. Theorists argue that, given the ambiguity of a single trial or context, word-referent associations can only be learned by comparing co-occurrence information across trials or contexts. Also known as cross-situational statistical learning.

**Cue availability:** The frequency of a given linguistic device in the language input and/or in a specific construction.

**Cue reliability:** The frequency with which a given linguistic device correctly identifies the roles of the arguments when available.

**Cue validity:** The information value of a linguistic device as a cue to underlying meaning. Cue validity is an objective property of the linguistic environment.

**Cultural evolution:** The evolution of behavioral traits that are not transmitted genetically but through social interaction, for example, via teaching or imitation.

**Curiosity:** An internal drive to explore the learning environment. See also ***Intrinsically motivated behavior***.

**Deictic gesture:** A gesture that relates the information to the communicative context (e.g., pointing).

**Derivational morphemes:** Changes to words that result in differences in their meanings. For example, adding "re" to the word "fill" produces a word with a different meaning, "refill," and adding "-er" to "sing" produces the new word "singer." As opposed to inflections, which distinguish forms of the same lexeme, derivations produce new lexemes. See also ***Lexeme*** and ***Inflectional morphemes***.

**Developmental language disorder (DLD):** A disorder that hinders a child's language acquisition. A child is diagnosed with DLD when the child's language skills (e.g., vocabulary or grammar) are significantly below expectations for the child's age and result in functional impacts on the child's everyday activities (e.g., academic achievement, peer interactions,

participation in family activities at home). DLD is generally diagnosed after the age of 4–5 years, when a persistent language deficit is indicative of poor prognosis. Non-verbal abilities are variable, and recent international consensus statements suggest that discrepancies between verbal and non-verbal skills should *not* be a requirement for diagnosis of DLD. Language disorder is a feature of many developmental conditions (e.g., autism), but in DLD the putative cause is unknown. DLD was previously known as specific language impairment (SLI).

**Didactic interactions:** Interactions in which one partner (usually an adult) explicitly teaches the other (usually a child) something (such as a word).

**Discourse markers:** Words and phrases such as "well," "you know," and "I mean" that provide information about how communication should be understood.

**Discrimination:** The act of telling two items apart. If perception is categorical, discrimination indicates that these items belong to two distinct categories (e.g., /ba/ and /da/, or red and orange).

**Distributional learning:** A type of statistical learning by which observers discover perceptual categories (e.g., phonemes) by tracking the relative frequencies of tokens in different regions of perceptual space (e.g., acoustic-phonetic space).

**Dizygotic twins:** A pair of twins originating from different zygotes. Also known as fraternal twins because they share on average half of their segregating DNA.

**Duration:** The length of a unit of speech, such as a speech sound (phoneme), syllable, or word.

**Dyadic interactions:** Interactions involving two people; in studies of child language this often refers to a parent and child.

**Dynamic system:** A system whose behavior over time is described by equations that compute the next state based on previous states.

**Egocentric view:** The viewer's first-person perspective, which is tied to the viewer's body and movement. Egocentric view changes dramatically over the first years of life.

**Electroencephalography (EEG):** A recording of brain activity. Information exchange between nerve cells takes place by electrical signals. The occurring electrical activity (summed over tens of thousands of neurons firing) can be measured with appropriate amplification and signal-processing techniques by means of the EEG. One common method is to average the EEG in response to many instances of a given stimulus, resulting in event-related potentials (ERPs).

**Ellipsis:** The omission of a linguistic form from a clause, which is nevertheless deducible from the context.

**Exemplar:** (1) A memory trace of a particular word or longer unit, including both perceptual and situational aspects. Situational aspects include indexical aspects of speech, such as the gender, emotional state, social class, or other vocally detectable characteristics of the speaker. (2) A single member from a category, often the first category member encountered. In the shape bias literature, children are often asked to extend a name for one exemplar to another.

**Exemplar cloud:** A collection of remembered instances of a single spoken form.

**Extratextual talk:** Any talk during a book-reading interaction that does not consist of the text of the book. See also ***Interactive reading***.

**Extrinsically motivated behaviors:** Behaviors carried out to satisfy an external need (e.g., tidying toys to elicit praise from a parent).

**Fasciculus:** A bundle of nerve fibers between distant brain regions. These are the axons of neurons that transmit information via electrical impulses. Important fasciculi of the language network are the arcuate fasciculus (FA) and the superior longitudinal fasciculus

(SLF), which constitute the dorsal pathway connecting Broca's area and the posterior temporal cortex. Diffusion imaging using MRI can be used to trace these pathways.

**Fast mapping:** The initial association between a word and a referent when the word is first heard, often in a matter of seconds. The term was originally coined by Susan Carey in the 1970s. Fast mapping may be completed using process-of-elimination among the potential meanings of a word. This initial association is very fragile and requires additional support and an extended slow mapping process for children to form a strong memory representation of the new word's meaning.

**Fillers:** Words or sounds used to indicate an upcoming delay in speaking (e.g., "um" or "uh").

**Finite-state grammar:** A simple form of generative grammar, which generates a linear structure based on the number of repetitions required (e.g., abn = ABABABABABA).

**Formants:** Prominent frequency bands in the speech signal, most typically in vowels, that result from vocal tract resonance. The combination of these formants, in particular the frequency of the first and second formant, renders vowel quality.

**Forward transitional probability:** A sequential statistical probability where the occurrence of a first unit (e.g., syllable) predicts the occurrence of a subsequent and immediately adjacent second unit (e.g., syllable). For example, given the sequence "kitten," the probability that "kit" will be preceded by "ten."

**Four-word point (4wp):** A half-hour recorded session in which the child produces at least four words spontaneously.

**Fricative:** A consonant produced with the articulatory organ (such as lip or tongue) creating an incomplete closure in the vocal tract, resulting in a noisy sound effect (e.g., the consonants of "five" or "shoe").

**Fundamental frequency:** The longest repeating pattern in the speech signal that results from vocal fold vibration. Adult males typically have a lower fundamental frequency (85–155 Hz) compared to females (165–225 Hz). It is perceived as the pitch of the voice and as such a key characteristic of speaker identity, and also signals intonation patterns. Also known as F0 ("F-zero").

**Gap:** The unfilled noun-phrase position associated with the relativized constituent.

**Geminate:** A phonologically long consonant.

**Generalization:** (1) Extending the name of an exemplar or category to a novel referent or context not previously experienced in co-occurrence with the name, based on the novel referent's or context's similarity to exemplars encountered previously. (2) Transferring knowledge of previously experienced exemplars to a novel, but similar, exemplar.

**Glide:** A consonant sound which is produced with very little obstruction of the airstream, sometimes called a semivowel. Examples of glides in English are the consonant sounds y and w in "you" and "wish" (written /i:/ and /u:/ in the International Phonetic Alphabet).

**Glottal stop:** The medial consonantal sound in "uh-oh."

**Guided play:** Play in which a more knowledgeable adult follows the interests and the lead of a child, imbuing the interaction with rich information that extends beyond what the child knows or can do on their own.

**Head-final:** Linguistic constructions in which the head (the lexical entry that determines the syntactic category of a phrase, such as a verb) follows its complements.

**Hearing aid prescription:** A formula that calculates the amount of gain and maximum output level required for people with different degrees of hearing loss. Hearing aids amplify sounds, and are adjusted for people with different degrees of hearing loss by applying a prescriptive formula.

**Hearing loss desensitization:** The reduction of speech information that can be extracted by a listener from an audible signal with increase in hearing loss.

**Heritability:** The extent to which a trait is determined to have genetic origins.

**Hotspots:** On-screen areas in digital applications that can be activated by the user to trigger a response.

**Iambic:** Stress pattern of a bisyllabic stress-bearing unit at the word level that starts with an unstressed (weak) syllable followed by a stressed (strong) syllable (e.g., "pro-POSE").

**Iconic gesture:** A gesture that displays in form or manner actions or properties associated with objects (e.g., flapping arms for "flying").

**Iconicity:** The perceived similarity between form and meaning; contrasted with the concept of arbitrariness. In the context of spoken language, a word is iconic when it sounds like what it means (e.g., "buzz" or "mushy").

**Inconsistent phonological disorder:** One type of speech sound disorder. This term is used to describe speech sound disorder that has a basis in children's phonological planning. Children with inconsistent phonological disorder present with inconsistent productions across word attempts. For example, "truck" may be pronounced as "tuck" or "twuck."

**Individual differences:** The variation within a given population on a particular trait or behavior. That is, individuals differ from one another on a particular measure (e.g., size or diversity of spoken vocabulary). Research on individual differences often seeks to explain the factors that contribute to such variation, or the impact of individual differences in one domain (e.g., vocabulary) on variation in another domain (e.g., reading).

**Infant-directed speech/action:** See ***child-directed speech/action***.

**Inferior frontal gyrus (IFG):** A brain area in the lower part of the lateral frontal lobe. The left IFG is a region of particular importance for language processing. It largely overlaps with Broca's area and is known for its role in the processing of syntactic but also semantic information. Brodmann's areas 44 and 45 fall within the scope of the IFG.

**Inflectional morphemes:** Changes to words that result in differences in their grammatical forms and meanings. For example, in English "-s" denotes third person singular in the present tense when added to verbs ("sings") and changes single nouns to plural form ("cat" to "cats"). Inflectional morphemes distinguish grammatical forms of the same lexeme such as "sing," "sings," "singing," and "sang." Inflectional morphemes are always used as a part of another word. See also ***Lexeme*** and ***Derivational morphemes***.

**Intelligibility:** A measure of how comprehensible speech is to a listener.

**Intensity:** A measure of energy in the signal. The physical intensity of a speech signal is its sound pressure level or amplitude. The perceived intensity is expressed in decibels (db). Intensity contributes to the perception of loudness and can vary between segments and intonation patterns.

**Interactive reading:** Interaction that occurs when adults go beyond reading the text to ask questions about pictures, print, or story events, or to link the story to the child's own experiences or knowledge base. These interactions can occur before, during, or after the reading of the text.

**Intonation:** Changes in fundamental frequency (falling or rising), intensity, and duration (long, short elements) conveying prosodic information relevant at the phrase or sentence level in speech.

**Intrinsically motivated behavior:** Behavior carried out for its own sake, motivated by internal mechanisms rather than external factors, e.g., motivated by intrinsic rewards like information gain, learning progress, or novelty, and associated with curiosity-driven

exploration. Additional examples include playing with toys, or listening to music. See also ***curiosity***.

**Invented spelling:** Early writing attempts in which a child produces letter-shaped forms that resemble the particular scripts to which a child is exposed. These productions can stand quite apart from conventional spellings but show the constructive nature of early literacy development. Invented spelling reflects the evolving nature of the conceptions the child holds about what writing is, its characteristics, and its functions. As an activity, invented spelling also seems an important means through which a child can gain insights about the relation between writing and language, as well as master the many writing conventions of the orthographies with which the child has contact.

**Iterated Learning:** The process by which a behavior arises in one individual through induction on the basis of observations of behavior in another individual who acquired that behavior in the same way.

**Joint attention:** Episodes in which two people (typically parent and child) are both focused on the same object or event.

**Knowledge telling:** A universal strategy for text production through which a writer probes memory for content and discourse knowledge associated with the particular writing assignment that a child is handling. Knowledge telling is commonly referred to as a think-say method of composing, by which a writer drains memory for a stream of associated knowledge that is elicited by the construed probes. While some tests of appropriateness might constrain what is written down, the risk of knowledge telling is that the text ends up resembling a wandering mind.

**Knowledge transforming:** An advanced strategy for text production through which the knowledge of the writer on a given writing topic is reprocessed, thus typically improving understanding and potentially producing rhetorically effective pieces of writing. What sets knowledge transforming apart from knowledge telling is the deliberative problem-solving nature that composing assumes. In knowledge transforming, both content and discourse knowledge are problematized and interact with each other. This mode of composing further allows for an interaction among the writer's goals and knowledge and the text written so far, resulting in the emergence of a truly reflective piece of writing.

**Labials:** Consonants produced with closure of the lips (e.g., b, m, p).

**Language Games:** Multi-agent computational (and sometimes robotic) models of language emergence in a population.

**Lexeme:** A unit of lexical meaning that roughly corresponds to the set of inflected forms taken by a single word. For example, the lexeme CAT includes the forms "cat" and "cats," and the lexeme SING includes the forms "sing," "sings," "singing," and "sang," but does not include the word "singer," which is a derivation. See also ***Inflectional morphemes*** and ***Derivational morphemes***.

**Lexical diversity:** A measure of the number of unique word types spoken.

**Lexical pitch accent:** Pitch pattern of a word (e.g., rising, dipping, flat) that is contrastive.

**Lexical stress:** Accentuation of syllables within words, which renders them more prominent than other syllables within the word. Also known as word stress.

**Lexical tone:** Pitch pattern of a syllable (e.g., rising, dipping, flat) that is contrastive.

**Linguistic typology:** The analysis, comparison, and classification of languages according to their common structural and functional forms.

**Liquids:** A consonant sound in which the tongue produces a partial closure in the mouth, resulting in a resonant, vowel-like consonant. English has two liquids, the consonants /r/ and /l/.

**Machine learning:** A domain that studies algorithms that can learn and make predictions on data.

**Magnetic resonance imaging (MRI):** A scan that generates high-resolution images of body tissue, including the brain. The angular momentum of hydrogen nuclei, also called nuclear spin, in a magnetic field leads to a centrifugal motion of the particles, which can generate a very small but measurable current in an applied coil. These electrical signals can be recorded, amplified, and assigned to specific locations in the magnetic field. This makes it possible to reconstruct three-dimensional high-resolution images of body tissue such as the brain. In addition, active brain areas can be identified in the brain because the increased metabolic activity and oxygen supply due to neural activity influence the signal generated. This activity-dependent signal change is also called BOLD (blood oxygen level dependent) contrast.

**Mirror neurons:** Neurons in the motor cortex that fire not only when an individual is acting or about to act but also when they perceive others performing an act that is within their own motoric repertoire.

**Monozygotic twins:** A pair of twins originating from the same zygote, and therefore sharing their segregating DNA.

**Morpheme:** The smallest blocks of meaning within a word (suffixes, prefixes, and root words). For example, "unhappy" consists of the two morphemes "un" and "happy," and "reopens" consists of three morphemes "re," "open," and "s."

**Morphological awareness:** The ability to recognize and manipulate morphemes.

**Mutual information:** The extent to which syllables within words are informative about each other. Mutual information incorporates predictive information in both forward and backward directions.

**Nasals:** Sounds produced by lowering the velum to allow air to pass through the nose (e.g., /n/ and /m/).

**Neighborhood density:** The number of words that are similar (phonetically or orthographically) in the lexicon. Neighborhood density is typically calculated by counting the number of insertions, deletions, and substitutions needed to transform a target word into the closest n neighbors (Phonological Levenshtein Distance) or by counting the number of words generated by replacing a single unity (phoneme or grapheme) at a time from a target word (Coltheart's N).

**Neural network:** Set of computer algorithms whose structures are inspired by biological neural networks. Information is processed through piled layers of interconnected units, the neurons. See also ***Connectionist model***.

**Non-adjacent dependency:** Units that co-occur over at least one intervening item. For example, in "The chapter I read was informative," the singular verb "was" co-occurs with the singular "chapter," but "I" and "read" are intervening items.

**NREM sleep:** Non-rapid eye movement sleep, consisting of increasingly deeper stages of sleep with different oscillatory brain activity, including stage 1 NREM (the lightest stage), stage 2 NREM (associated with spindle activity), and slow wave sleep, the deepest stage of NREM, consisting of slow, high amplitude activity.

**Nucleus:** The part of the syllable that follows the onset (a vocalic portion with or without a coda following; the vowel may be a diphthong).

**Object exploration:** Play involving sensorimotor exploration of objects, including banging, mouthing, touching, rotating, and visually inspecting an object.

**Onset:** The consonant slot at the beginning of a syllable. It may include more than one consonant, depending on the language. Words beginning with vowels do not have onsets.

**Open-class words:** The class of words in a language that can be defined by reference to some external event, thing, quality, or state (e.g., "dog," "dancing," "crying"). New open-class words are created easily and frequently.

**Oromuscular:** The muscles of the mouth, tongue, lips, and face. An assessment of children's oromusculature often includes the observation of children's facial anatomy both at rest and during movement (with or without producing sounds).

**Overhearing:** The act of listening in on or eavesdropping on a conversation that one is not actively involved in.

**Palatals:** Consonants produced by raising the mid-part of the tongue toward the palate, or roof, of the mouth (e.g., the y in "yes").

**Patient:** A participant in an event on whom the action is realized.

**Perceptual attunement:** The process of tuning general perceptual abilities to be specific to the environment. Of speech: the process of learning to discriminate between segments that are phonemic in one's native language, and learning not to discriminate between segments that are not phonemically contrastive.

**Perceptual-magnet effect:** The warping of speech perception depending on whether tokens are prototypical or peripheral examples of a given category. Discrimination between tokens of the same phoneme category is worse around tokens that listeners consider prototypical exemplars of the category, and better around tokens that listeners consider poor or peripheral exemplars of the category. As phoneme categories and their exact prototypes are language specific, so is the perceptual-magnet effect.

**Perceptual narrowing:** An experience-driven process by which an infant homes in on relevant distinctions in the environment, while also learning to ignore less relevant perceptual information.

**Phoneme:** The smallest unit of meaningful acoustic speech information. Phonemes distinguish one word from another within one language and can be divided into categories such as /a/ or /e/ (e.g., "bat" versus "bet").

**Phonetic contrast:** Acoustic differences in the way words are pronounced that create similar but functionally distinct sounds. For example, the sound /p/ in English is produced with a puff when produced in word-initial position, but not when produced before another consonant (e.g., "ping" versus "spring"). This phonetic variation does not change the meaning of a word (e.g., "speak" has the same meaning in English whether the /p/ sound is pronounced with or without a puff).

**Phonetics:** The study of the physical realization of speech, including production, acoustics, and perception. Phonetics is often contrasted with phonology, which is the study of the abstract representation of speech.

**Phonological:** Components of language that are based on the rules and/or constraints of speech sounds in a language.

**Phonological awareness:** An awareness of the sound structure of spoken language. For example, phonological awareness is the ability to identify that the word "bus" has three phonemes /b/-/ʌ/-/s/ and that removing the first sound of "bus" creates a new word, "us."

**Phonological error patterns (phonological processes):** Patterns of speech sound errors that occur in children's speech (these may also be called phonological processes). Phonological error patterns may be developmentally appropriate at different ages. Atypical phonological error patterns are those that are not developmentally expected in the language. For example, in English, the fronting of velar plosives (e.g., "cat" /kæt/ produced as [tæt]) may be developmentally appropriate, but backing of velar plosives (e.g., "tin" /tɪn/ produced as [kɪn]) is not observed in typical phonological development.

**Phonological impairment:** A type of speech sound disorder that has a cognitive-linguistic basis. Children with phonological impairment demonstrate a lack of awareness of the meaningful contrasts between sounds and present with phonological error patterns when producing words.

**Phonological memory:** The ability to briefly retain auditory patterns in mind.

**Phonological processing:** The analysis, systematic manipulation, and storage of the sounds of a given language. Phonological processing is composed of phonological awareness (the ability to consciously analyze and manipulate the sounds of a language), phonological working memory (the ability to store phoneme information), and phonological retrieval (the ability to recall the association between phonemes and graphemes).

**Phonology:** The study of the sounds occurring in language, e.g., phonemes, in which all phones belonging to the same phoneme category are summarized. Phones describe the detailed variation of all possible human articulated sounds. This variation may not lead to meaningful differences. The number and boundaries of phoneme categories differ between languages. For example, German speakers produce and perceive /v/ and /w/ as variations of the same category, whereas English speakers have two phoneme categories.

**Phonotactic probability:** The frequency of individual sounds and sound combinations in a given position in a word in a particular language. Phonotactic probability is calculated by dividing the total frequency of a given sound sequence (e.g., /st/) in a given position (e.g., first phoneme) by the total frequency of any sound sequence occurring in that given position.

**Phonotactics:** The study of sequences of sounds that are typically produced in a language. Each language has a unique set of phonotactic constraints. These constraints determine which combinations and sequences of phonemes are permissible in each language. For example, Dutch allows /kn/ consonant clusters ("knop"), whereas English does not.

**Phonotactic structure:** The sound segments within words according to consonant and vowel positions (C and V are used to denote consonants and vowels, respectively). For example, the phonotactic structure of "cat" is CVC, that of "pumpkin" is CVCCVC, and that of "elephant" is VCVCVCC.

**Pitch:** A listener's perception of fundamental frequency as "high" and "low" sounds. See also ***fundamental frequency***.

**Polyadic interactions:** Interactions involving more than two people.

**Pragmatics:** The study of how listeners use contextual factors to bridge the gap between underspecified communicative signals (typically in the form of linguistic utterances, but also gestures, facial expressions, and others) and full-fledged speaker meanings. Pragmatics research on production examines how speakers tailor their utterances to the communicative needs of their interlocutors and the utterance situation, in line with their preferences and abilities.

**Predicates:** The part of sentences that provides information about the subject of the sentence (e.g., in the sentence "the boy likes to read books", "likes to read books" is the predicate).

**Primary distributional learning:** The registering of regularities in the speech stream. See also ***Secondary distributional learning***.

**Proprioception:** The feeling of one's body movements in space.

**Prosody:** The rhythmic or intonational characteristics of a language that manifest themselves through the variation of the voice, including sentence melody, stress, pitch, and pauses. For example, the raising of the voice at the end of an interrogative sentence belongs to the prosodic qualities of language.

**Real-ear measurements:** Measurements of the level of a sound in a person's ear canal, close to the eardrum. Real-ear measurements are often used to check that hearing aids have been adjusted to match the targets prescribed by hearing aid prescriptions.

**Referential or symbolic word use:** Word production that occurs outside of any priming context and refers to word categories rather than to specific referents.

**Referent selection:** The act of identifying a possible referent of a new word's meaning, often through touching, picking up, or pointing to an object. Referent selection may refer to an experimental task used to test fast mapping, typically involving presenting a series of objects for which a child knows the names with a single novel, name-unknown object that is the intended referent of a new word.

**Register:** A subset of forms of a language that is typically restricted to usage in a specific context. The register called "child-directed speech" consists of a high and varied pitch, among other characteristics, and is restricted to interactions with young children, particularly infants.

**Relational analyses:** A type of analysis which provides information about how a child's speech compares with the adult or target speech. It typically includes a phonological process analysis (i.e., the identification of phonological error patterns, the variability of these errors, and the patterns of errors across phoneme class, word position, and syllabic context), analysis of lexical stress accuracy, and overall intelligibility.

**REM sleep:** Rapid eye movement sleep, a stage of sleep that is marked by fast, low amplitude brain activity, rapid eye movements, and muscle atonia. REM sleep is predominant in the later part of nocturnal sleep.

**Residual articulation errors:** Articulation errors that continue to persist, e.g., after a treatment is completed or into adulthood.

**Retention:** The robust storage of a word's meaning in long-term memory, enabling retrieval and recognition after a delay or when the word is encountered in a new context.

**Rhythm:** Rhythmic aspects of speech related to its temporal duration and other suprasegmental acoustic regularities (e.g., intensity, pitch).

**Robotic model:** A model using a robotic body, which can be physical or simulated.

**Schwa:** The vowel used most frequently in English unstressed syllables, such as in "bottle," "button," and "carpet."

**Secondary distributional learning:** The registering of regularities in known word forms. See also ***primary distributional learning***.

**Segmental:** Phonetic and phonological characteristics that are restricted to a single segment, i.e., at the speech sound level.

**Segregating DNA:** The process by which chromosomes 1 to 22 and sex chromosomes X and Y undergo replication and separation in meiosis.

**Self-organization:** A property of certain systems where order at a macro-level arises from the interaction of components at a micro-level, while being different from the organization of this micro-level.

**Semantic processing:** The encoding and storage of meanings of a word and the establishment of relations among words with similar meanings (e.g., "pen" and "pencil" are both writing tools).

**Semantics:** The study of linguistic units that convey meaning and of how words are related via meaning (e.g., "cat," "dog," "animal"). Semantics may also focus on how words are broken down into meaningful parts (morphemes). Morphological elements like "un" in "unhappy" belong to derivational morphology and are part of semantics.

**Sensorimotor learning:** The learning of the correspondences between actions and their perceptual outcomes.

**Shape bias:** The tendency to generalize the names of novel solid objects to other objects that share the same shape, rather than to other objects that share another feature (e.g., the same texture or the same color).

**Shared book-reading:** Adult-child interactions while looking at and/or reading a picture book, ranging from simple board books to more complex narrative and expository texts in traditional print or electronic formats.

**Sleep spindles:** Bursts of oscillatory brain activity believed to correspond to memory consolidation and other sleep-related functions.

**Slow wave sleep:** Sleep that is marked by slow, high amplitude brain activity (slow wave activity). Slow wave sleep is predominant in the early part of nocturnal sleep.

**Spectral information:** The frequency information in the speech signal beyond the fundamental frequency. Typically represented using a spectrum or spectrogram. See also ***fundamental frequency*** and ***formants***.

**Speech segmentation problem:** The challenge of extracting words from speech. The speech segmentation problem is especially challenging for infants because they cannot rely on lexical knowledge, and speech input typically comprises mainly multi-word utterances, with no pauses between words to reliably mark word boundaries.

**Speech sound disorders:** Disorders related to children's perception and/or production of speech sounds. These disorders may be due to known or unknown etiology.

**Stability:** The consistency of individual differences on a particular trait over time. A trait is stable if the rank order of individual performance remains the same over time, even if the mean difference in performance increases or decreases. In dynamic systems theory, stability refers to an individual's ability to continue to behave as before despite perturbations.

**Stops:** Consonants produced with complete closure in the vocal tract (e.g., g).

**Superior temporal gyrus (STG):** A brain area in the upper part of the temporal lobe. Wernicke's area largely falls within the left STG and is part of the left hemispheric language network.

**Supraglottal consonant sounds:** Consonant sounds produced by obstruction of the airflow within the oral or pharyngeal cavity, above the glottis or vocal folds. Examples of supraglottal sounds are /b/, /p/, /d/, /t/, /g/, /k/, while /h/ is a glottal sound.

**Suprasegmental:** Phonetic and phonological characteristics that are not restricted to a single segment (i.e., that go beyond the level of speech sounds). Suprasegmental phonetic characteristics include pitch, loudness, and duration. Suprasegmental phonological units include the syllable, foot, and phrases.

**Symbolic gesture:** A gesture that is used to stand for an object or action and that remains stable across different contexts (e.g., waving hands for "hello").

**Symbolic play:** Play in which children enact scenarios with objects, sometimes using one object to represent another, including bouts of pretend play (enacting a tea party), substitution play (using a stick as a spoon), and sociodramatic play (taking on different roles, such as doctor and baby).

**Syntactic category:** Word classes (e.g., verb, noun, preposition, etc.) and phrasal classes (verb phrase, noun phrase, prepositional phrase, etc.) in a language that are based on similar structure.

**Syntax:** The system of rules determining the possible combinations of linguistic units. By these rules words are joined together to form sentences, which can become arbitrarily long. Depending on the order of words, the meaning of the linguistic content may even change

or be accentuated. The subarea of morphosyntax describes the rules according to which word stems and suffixes can be combined within words, for example, in the conjugation of verbs (e.g., adding an "-s" to create a third person singular verb in the phrase "the dog jumps").

**Template:** A familiar pattern used to assimilate challenging word targets to existing motoric patterns. For example, a child may have the template "Consonant-Vowel-Consonant-i" <CVCi>, which fits words in the lexicon such as "doggy" and "bunny."

**Thematic roles:** A set of semantic roles that is associated with a verb (e.g., agent, patient, source, goal, etc.).

**Theme:** A participant of an event on which the action is realized, usually inanimate.

**Third-party learning:** Learning from observing an interaction that one is not involved in.

**Top-down:** A learning process in which new knowledge is acquired from existing knowledge. For example, knowledge of segmental or suprasegmental categories in speech are learned from lexical knowledge (i.e., word forms or word-meaning combinations). Compare ***Bottom-up***.

**Transcription:** A necessary writing process through which language is externalized and given a visible and permanent format. Transcription draws on the close integration between spelling and handwriting (or typing). Transcription requires the intertwining of orthographic knowledge and the motor movements required by the particular writing tool that makes language visual.

**Translating:** In models of text production, the cognitive processes through which ideas are given a linguistic form. It is normally assumed that the contents of such translation are temporarily kept in phonological short-term memory, from which they can feed motor execution systems (e.g., articulation or handwriting). Thus, translating includes an array of processes that are typically considered under spoken language production. Some models of writing further subsume transcription under translating processes.

**Trochaic:** Stress pattern of a bisyllabic stress-bearing unit at the word level that starts with a stressed (strong) syllable followed by an unstressed (weak) syllable (e.g., "KING-dom").

**Twenty-five word point (25wp):** A half-hour recorded session in which the child produces at least 25 words spontaneously.

**Typological similarity:** The similarity of languages that share many of the same structural characteristics (e.g., French and Spanish are typologically similar, but French and Chinese are typologically different). See also ***Linguistic typology***.

**Usage-based model:** A framework that conceptualizes language development and language change as directly affected by language use. For development, this implies that preverbal vocal practice and word production both contribute to word-form learning.

**Velars:** Consonants produced with the back of the tongue touching or approaching the palate, or roof, of the mouth (e.g., /k/).

**Vicarious word learning:** Learning the meanings of a word by watching it being used by people one is not engaged with.

**Video chat:** A real-time audio and video communication involving at least two people who are not physically present in the same space.

**Video deficit effect:** A domain-general pattern in which children learn more from in-person interaction than from video experiences.

**Vocabulary knowledge:** Knowledge of the pronunciation, spelling, and meanings of words.

**Vocal motor scheme:** A consonant produced with relatively high frequency and consistency over the course of several recorded and transcribed sessions.

**Vocal tract:** The sequence of cavities from the vocal folds (in the larynx) to the lips, including the pharyngeal cavity, oral cavity, and nasal cavity. The shape and size of the vocal tract differs between speakers as a result of anatomical differences, as well as within speakers as a result of (speech) articulation. See also ***formants***.

**Vowel harmony:** A phonological phenomenon in some languages (e.g., Turkish, Hungarian) whereby vowels of a word show systematic similarity in some aspect of the way they are pronounced (e.g., frontness and backness).

**Word relatedness:** A task that measures an individual's breadth of vocabulary knowledge by asking the individual to provide words with similar (synonyms) or opposite (antonym) meanings to a target word.

**Word usage:** A task that measures an individual's ability to use multiple meanings of a target word in different sentences to assess their breadth of vocabulary knowledge.

**Writing fluency:** The efficiency with which written language is produced, commonly measured in words per minute. Pauses and bursts of written language production are main contributors to writing fluency. Developing expertise in writing does not necessarily imply a continuous growth of writing fluency. Knowledge telling models would predict a continuous growth of writing fluency. In contrast, due to its deliberative and effortful nature, knowledge transforming should stop a continuous growth of writing fluency, perhaps limiting writing fluency to a plateau or optimal level. See also ***Knowledge telling*** and ***Knowledge transforming***.

**Writing system:** A conventional method of visually representing verbal communication. Written languages differ in the linguistic units in the spoken stream that they try to map. Major divisions in these mappings tend to occur at the boundaries of morphemes, syllables, or phonemes. Writing systems are logographic when a character stands for a meaningful unit of language (e.g., a morpheme). Characters can also stand for meaningless sound units that build up morphemes; this is the case in syllabaries (mapping syllables) or alphabetic scripts (mapping phonemes). Prototypical examples include the following: Sumerian cuneiform script maps morphemes, Japanese Kana maps syllables, and the Greek alphabet maps phonemes. Many scripts tend to point to a few or to a mix of language units. Thus, scripts categorized as abjads (representing mainly consonants), morphosyllabic, or alphasyllabic are frequent.

**Yod:** The glide sound at the onset of "you." See also ***Glide***.

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