17 Psycholinguistics

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"Neither can embellishments of language be found without arrangement and expression of thoughts, nor can thoughts be made to shine without the light of language."

—Cicero

Human language is seated in each and every normally developed, neurologically healthy human mind. It is the outward expression of language, however, with which most people are familiar: language comprehension and production during the course of spoken, signed, or written communication. Noam Chomsky has often said that if people could simply beam thought directly into each other's brains, we would have no need for language, nor for the intricacies of phonology, morphology, syntax, and the other subcomponents of language elucidated in the chapters of this volume. As it happens, however, language use requires the formal structure of language to interface with other cognitive functions, and these interfaces operate under certain constraints. For example, although language and communication can be dissociated, language is generally used for communication. Because we do not in fact have the aforementioned ability to communicate via telepathic thought, language is temporally constrained. The mouths of speakers and hands of signers are limited in their mobility, and are therefore able to produce essentially one sound, word, or sign at a time. Language production is therefore inherently incremental and serial. Consequently, language comprehension is also incremental, more or less yoked to the unfolding input, be it aural or visual. Psycholinguistics is the study of the interfaces between language structure and language use: between thought and production, production and comprehension, and comprehension and thought, as well as the many other cognitive systems that shape the use of language as it is flowing into and out of the mind in real time. I begin with a (very) brief, quite recent history of the field. In actuality, psychologists have been interested in language since the very inception of psychology as a discipline, as detailed in fascinating detail by Levelt (2012). The "Cognitive Revolution" in the 1950s (Miller 2003) led to closer ties between the psychological study of language and the linguistic study of language, and this is where the following brief chapter will begin. We will then focus on a few central issues in comprehension and production, concluding with a (small) sampling of psycholinguistic research examining how these capacities develop both in children as they learn their native languages and in adults learning foreign languages.

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1 Psycholinguistics as a Field of Study

Fernanda Ferreira aptly describes the relationship between formal linguistics and psycholinguistics as a complicated "family relationship" (2005: 365), and interested readers are encouraged to refer to Ferreira's accessible outline of how the two fields have complemented each other over the past 60 plus years since the Cognitive Revolution (and her advice as to how to make "family reunions" somewhat less awkward). Space limitations preclude the inclusion of a satisfactory account of the historical record here. Common linguistic and cognitive threads are woven throughout the history of psycholinguistics, however, which are worth noting. One is the tension between linguistic theories on one hand, and the capacity-limited processing characteristics of the human mind. While the former seek to capture crosslinguistic generalities in the most perspicuous and elegant way possible, the latter must necessarily view these theories through the lens of actual human performance, and, as noted above, performance entails certain constraints. For example, whereas much generative syntactic theory conceives of syntactic structure as being derived essentially from the "middle out" (e.g., Government and Binding Theory: Chomsky 1981; Minimalism: Chomsky 1995; Epstein and Seely 2006), language unfolds over time "left to right."

This theoretical difference in perspective is reflected in the tension in psycholinguistics between "bottom-up" processing and "top-down" processing (e.g., Gibson 2006; see Clark 2013, for an excellent discussion of this tension in all aspects of cognition). Bottom-up describes processing that begins with the lowest level representations available, say, phonemes, and takes the output of that processing level as the input of the next level, say, syllables or morphemes. In strictly serial, bottom-up processing, higher levels of representation should have no influence on lower levels. Top-down describes processing that works in the opposite direction: higher levels of information are used to predict the content of upcoming lower level input and perhaps influence its ongoing integration. The bottom-up aspect of language processing may seem more intuitive at first blush; for example, given a picture of a boy, several toys, and a cake, people are not terribly accurate at predicting the upcoming word in the sentence "*The boy will move the* ___," as measured by the timing of looks in eye movement monitoring experiments to the cake compared to timing of looks to the other objects in the picture (Altmann and Kamide 1999). Yet top-down effects, upon reflection, are also readily apparent. Reicher (1969) documented a "word-superiority effect" for letter identification, such that it is easier to recognize letters when they are presented in words compared to when they are presented in nonword strings or by themselves. Similarly, imagine a slight revision of the sentence above: "*The boy will eat the* ___." People are more likely to look at the cake sooner with this more specific context, in which the cake is the only object in the picture that is edible (Altmann and Kamide 1999; cf. Tanenhaus et al. 1995). Reading times on more predictable words have also been shown to be shorter than on less predictable words, controlling for word length and frequency (Rayner and Well 1996), suggesting that less computational effort is required to identify predictable words during reading (Rayner 1998). Furthermore, predictions about upcoming words during reading do not seem to contain only rough semantic information. Instead, these predictions include, when the context is narrow enough, information about phonological characteristics of the word (Laszlo and Federmeier 2009) and even letter order (Luke and Christianson 2012).

The present era of psycholinguistic research is particularly exciting, as this tension, which has been present from the days when psycholinguistics emerged as a unique field of study, is being addressed with the aid of powerful new methods, including brain imaging and computational modeling. The remainder of this chapter will highlight some of these efforts, and point toward future research that would appear to be logical extensions of today's most thought-provoking work.

2 Language Production

Thought is instantaneous and holistic, but speech is necessarily sequential and segmental. A great deal of research in language production has sought to clarify how amorphous thought gets squeezed out through the bottleneck of linear speech. The most influential model of speech production was developed by Levelt (1998; Levelt, Roelofs, and Meyer 1999), and it has generated a great deal of research ever since. Within this model, a message is first generated and associated with lexicalized concepts. Next, the message passes on to a "formulator," whose job it is to determine the grammatical properties of the lexicalized concepts and associate those concepts with lemmas (word forms) from the lexicon, including appropriate morphological forms. Next, the phonological properties of the lemmas are filled in, and finally, articulation commences.

It is clear from this brief sketch of the Levelt production model that there is considerable leeway as to the amount of planning that may occur in speech production. Returning to the tension between bottom-up and top-down processing, one might imagine a model of speech production in which speakers simply produce the first, most conceptually accessible or salient entity that comes to mind and then try to fill in a licit syntactic structure from there. Such a system has been termed "radically incremental" (Ferreira and Swets 2002). Although such a model has been proposed to account for some production data (e.g., De Smedt 1990; Kempen and Hoenkamp 1987; van Nice and Dietrich 2003), it has generally been dismissed (e.g., Bock 1986) as unrealistic. Difficulty arises, however, in decisively ruling out strictly word-by-word incrementality in languages like English, in which conceptual accessibility, syntactic structure, and linear order are badly confounded. For example, Bock and Warren (1985) demonstrated that if people read the word *worship* and are then shown a picture of lightning striking a church, they are more likely to describe the church in the passive voice (*The church is struck by lightning*) than if they had previously read a word that was semantically unrelated to the concept "church." Bock and Warren interpreted this finding as showing that the most conceptually accessible entity claims not only the first position in the string, but also the most prominent syntactic position. As noted, though, English is not a particularly good language in which to examine these issues, as subjects tend to come first in English sentences, and both discourse topics (i.e., "given" information) and thematic agents (i.e., "doers" of actions) tend to be subjects. Furthermore, English does not have any special morphological marking for discourse topics or thematic agents, or syntactic subjects, for that matter.

As it turns out, other Indo-European languages are not much better suited as testing grounds for language production models (Levelt 1998). Recently, researchers have begun to examine production in non-Indo-European languages with the aim of disentangling syntactic, semantic, and discourse factors affecting language production (e.g., Christianson and F. Ferreira 2005; V. Ferreira and Yoshita 2003; Yamashita and Chang 2001). The study by Christianson and F. Ferreira allowed for the dissociation of these factors by examining production in the indigenous North American Algonquian language Odawa. Without going into detail about the morphosyntax of Odawa, suffice it to say that the language has a number of characteristics (Valentine 2001) that make it intriguingly dissimilar from languages previously studied by psycholinguists: a broad inventory of verb forms, a complex agreement system of nominal and verbal morphology that is not technically case marking, pro-drop (the omission of noun arguments), and extremely flexible word order (all six logical word orders – SOV, OSV, SVO, OVS, VSO, VOS – are possible and are used). These features combine in Odawa to make it possible to utter the word for any conceptually accessible entity first without having to change the underlying syntax or to use a less frequent verb form, both of which are the case in English. The results from Odawa, however, point to mechanisms of language production that are similar to English, despite the typological distance between the two languages. Odawa speakers altered the syntactic structures they used to describe pictures in response to question prompts that highlighted either the thematic agent, thematic patient, or neither; they did not just spit out the first word that came to mind. Taken together, the Odawa results supported conclusions drawn by V. Ferreira and Dell (2000), who proposed that production is not a figurative "race" out of the mouth. Instead, syntactic structures are chosen to accommodate highly activated concepts at the message level; if a highly activated concept is a thematic patient, that property mediates the selection in English of a passive structure, which serves to align the thematic, syntactic, and discourse status of the entity with the first position in the utterance. This view of language production can be termed "weakly incremental."

Related evidence of syntactic effects on language production can be found in the extensive literature on syntactic, or structural, priming. This literature is based on the observation by Bock (1986) that people tend to repeat recently heard or spoken syntactic structures to encode new information. For example, if you happen to hear a sentence such as *The president gave the Congress an ultimatum*, you are more likely to say *The girl handed the boy a flower* than the meaning-equivalent alternative *The girl handed a flower to the boy* to describe a picture of a girl handing a flower to a boy. The literature exploring this priming effect is enormous, and well beyond the scope of this chapter to even summarize. The interested reader is encouraged to refer to an excellent review of structural priming by Pickering and V. Ferreira (2008); however, a few intriguing findings are worth noting here. It is possible that explicit memory for the content or structure of a sentence results in structural priming (Bock and Griffin 2000; Chang, Dell, and Bock 2006; Hartsuiker et al. 2008), as suggested by the observation that priming rates are "boosted" when verbs are repeated from the prime in the production (e.g., Hartsuiker et al. 2008). The possibility that this is the only mechanism underlying structural priming appears to be ruled out, however, by evidence that priming persists over up to ten intervening sentences (Bock and Griffin 2000). More strikingly, structural priming effects have been observed in amnesic patients who have no explicit memory for the prime sentences (V. Ferreira et al. 2008). Finally, evidence is accruing that abstract syntactic structure is shared between languages in the minds of bilinguals despite the lack of lexical or even word order overlap between the two languages (e.g., Korean and English) (Shin and Christianson 2009, 2011; cf. Chen et al. 2013; Hartsuiker, Pickering, and Veltkamp 2004; Kantola and van Gompel 2011).

Language production thus appears to involve a degree of planning (e.g., Garrett 1975; Mackay 1972), but it is important to note that no one believes entire sentences are planned out before speaking commences in normal conversational settings. Although it is not yet known for certain what the range of planning is (see Konopka 2012), a good approximation appears to be more or less one clause. Speech error data provide evidence along with the studies cited above that converge on the primacy of the clause in language production planning. Consider this speech error, reported in Jaeger (2007): *My sore is really … My throat is really sore*. This is an example of an anticipatory error in that a word farther along in the message is produced too soon. It is typical of anticipatory speech errors, the vast majority of which occur inside a single clause (Garrett 1975). On the other hand, it is a bit unusual in that an adjective (*sore*) is produced in place of a noun (*throat*). Perhaps the error signal associated with this cross-category swap alerted the speaker that something was wrong so that the utterance was interrupted and corrected mid-sentence. An example of a complete exchange between two nouns, reported by Garrett (1975), was not interrupted in this way: *Stop beating your brick against a head wall*. Errors in which substituted words and intended words are from the same category are far more common than errors in which words from different categories are exchanged (Dell 1986; Postma 2000).

Before closing this section, it is important to note the growing body of literature on language production in more naturalistic tasks, such as actual conversations between two people. This research has demonstrated that the linguistic expression of a message is affected significantly by elements of preceding discourse, the visual information in the immediate environment, and the perceived joint attention of both speaker and listener. Speakers in a conversation tend to align referential forms, using the same, often tacitly agreed upon, terms for entities (Brennan and Clark 1996; Clark and Wilkes-Gibbs 1989; Wilkes-Gibbs and Clark 1992). They modify referential expressions according to task demands and likelihood of confusion on the part of the listener (e.g., Brown-Schmidt, Campana, and Tanenhaus 2005; Brown-Schmidt and Tanenhaus 2008). Some research has also shown that speakers monitor their ongoing beliefs about the ease of comprehension on the part of addressees and modify the syntactic structure of utterances in order to avoid ambiguities (Haywood, Pickering, and Branigan 2005). In short, speakers in conversational settings appear to adjust their utterances on the fly as dictated by their perception of the listener's comprehension and the contents of the environment – a strikingly top-down influence on language production.

Speakers are not perfect at doing this, however. In contrast to Haywood, Pickering, and Branigan's (2005) results, neither Arnold et al. (2004) nor Kraljic and Brennan (2005) found evidence that speakers avoided syntactic ambiguities in deference to their addressees' ease of comprehension. With respect to referential forms, Englehardt, Bailey, and F. Ferreira (2006) show that whereas speakers are good at avoiding underspecified descriptions of entities in a scene, they are less good at avoiding overspecified descriptions of entities. In other words, people often produce descriptions with more information than is strictly necessary in a given situation, and listeners do not seem to judge these overdescriptions to be worse than more perspicuous descriptions. Continued work is needed to determine how more top-down considerations of addressee and conversational context and content are balanced against more bottom-up concerns about the visual characteristics and immediate salience of entities in conversations. Thorough summaries of recent psycholinguistic work in this area can be found in Konopka and Brown-Schmidt (2014) and Trueswell and Tanenhaus (2005).

3 Language Comprehension

Imagine that you want to learn about how a car engine works. So you find an engine that is running smoothly, and you open the hood. What would you learn by simply watching the engine running at its normal speed? The answer is likely not too much, simply because the engine is running very fast, and the connections between the various parts are too tightly linked to observe with the naked eye. In order to truly learn how each subcomponent of the engine operates and, in turn, interacts with other subcomponents, you would need to slow the engine down somehow – take out parts or introduce anomalies into the system somewhere, maybe even a literal monkey wrench. An analogous difficulty faces psycholinguists who study language comprehension: Comprehension is normally so fast and so smooth that it is nearly impossible to observe. As such, psycholinguists need a figurative monkey wrench to throw into the works. The most oft-tossed figurative wrench is ambiguity.

Ambiguity refers to situations in which a word (lexical ambiguity; see example (1) below, where *bank* is ambiguous) or sentence (structural ambiguity) can have two or more interpretations. There are also two subtypes of structural ambiguity, temporary and global. Temporary ambiguities (see example (3)) can be resolved by reading or listening to the rest of the sentence; global ambiguities cannot (see example (4)). Ambiguity is not the same thing as vagueness. Example (2) is simply vague because we do not know what Jack knew. Example (3) is temporarily ambiguous, and an initial, partial interpretation that "Jack knew the secret" must be revised to be interpreted correctly, specifically, that "Jack knew something about Jill, and that something is that the secret was bothering her." Note that example (3) does not technically state that Jack knew what the secret was. Example (4) is globally ambiguous because we do not know whether Jack was using a secret to blackmail the woman, or whether he was blackmailing a woman who had a secret (possibly wholly unrelated to the blackmail plot).

(1) Jack hid his ill-gotten gains in the bank by the river. (lexical ambiguity)

(2) Jack knew something. (vagueness)

(3) Jack knew the secret bothered Jill. (temporary structural ambiguity)

(4) Jack blackmailed the woman with a secret. (global structural ambiguity)

It is reported that around 40 percent of words in English are ambiguous (Traxler 2012), and a good bit of research has been conducted examining what happens in the mind when ambiguous words are encountered. The consensus of most of this work (e.g., Onifer and Swinney 1981; Seidenberg et al. 1982; Swinney 1979) is that all meanings of a word are accessed immediately, and very quickly thereafter (in less than 250 msec) the meanings that are unrelated to the immediate context are inhibited, leaving only the appropriate meaning behind.

When it comes to structural ambiguity, temporary structural ambiguity has proven to be particularly useful in slowing down the language comprehension system without forcing it to grind to a complete halt in the form of irreconcilable confusion (though see the discussion of interpretation below for some new findings). Sentences such as (3) have been termed "garden-path sentences" (Bever 1970) because they lead a reader or listener down a figurative garden path, which, at some point, is shown to be incorrect or misleading, and must be traced back to the error to recover from it. The initial error signal, and the subsequent recovery process, can be observed by psycholinguists in the form of disruptions to normal eye movement patterns during reading (e.g., Frazier and Rayner 1982; Pickering and Traxler 1998; Rayner 1998; Trueswell, Tanenhaus, and Garnsey 1994); eye movement patterns looking around scenes while listening to language (e.g., Tanenhaus et al. 1995); and patterns of brain waves called event-related potentials (ERPs) (e.g., Friederici 1998; Kutas, van Petten, and Kluender 2006) which are recorded via electroencephalography (EEG).

A critical factor in why we appear susceptible to these so-called garden-path disruptions is the "immediacy principle" proposed first by Just and Carpenter (1980). This principle states that, as much as possible, we derive interpretations from incoming language input immediately as it comes in, i.e., sequentially, word by word (Altmann and Kamide 1999; Marslen-Wilson and Tyler 1975; Tanenhaus 2007). We do not as a matter of course wait around to hear or read an entire sentence before we begin locating lexical meanings for words, constructing syntactic structure, and interpreting the meaning of the combined input. As a result, when we get to *the secret* in (3), we have built a syntactic structure in which *knew* takes a direct object, and *the secret* fills that slot nicely, so it gets automatically attached as the direct object. In general, the syntactic parser prefers to fill all possible argument positions in the simplest possible way, rather than closing off the verb phrase or positing more complex continuations for incoming material. Frazier (1978) proposed two syntactic parsing principles that captured these preferences, respectively: Late Closure and Minimal Attachment. These two principles have been the source and subject of hundreds of studies ever since, and, although they have been questioned and scrutinized on various grounds, they appear to be deeply entrenched preferences held by the human sentence processing system across languages.

Continuing with (3), the problem then arises when we get to the verb in the subordinate clause, *bothered*; this verb needs a subject, and *the secret* is the only option (in English). In order to assign subject status to *the secret*, it must be removed from object position of *knew*, and the resultant object role must be reassigned to the entire subordinate clause. As noted above, this process of "syntactic reanalysis" can be observed to some extent by looking at psychobehavioral measures such as eye movements during reading, which are tracked using infrared eye trackers. Frazier and Rayner (1982) provided the first eye-tracking evidence of syntactic reanalysis, documenting robust "garden-path effects" of re-reading, in the form of leftward eye movements (regressions), upon encountering disambiguating words (such as *bothered* in (3)).

The immediately preceding description of syntactic reanalysis assumes a certain theoretical position, however. Specifically, this theoretical position assumes that syntactic structures are built up not only incrementally, but also initially in the comprehension process and, importantly, independently of nonmorphosyntactic information sources (i.e., bottom-up). This view of syntactic parsing in sentence comprehension motivated so-called serial, or two-stage models of syntactic parsing. These models are based conceptually on the view of the mind as having a compartmentalized, or modular, architecture (e.g., J. A. Fodor 1983), within which certain processes operate over only very specific types of information. This idea leads to a view of sentence parsing that (a) takes as primary the syntactic structure-building process, and (b) uses in this process only syntactic information at the first stage of parsing (e.g., Frazier 1978, 1987; Frazier and J. D. Fodor 1978; Rayner, Carlson, and Frazier 1983). The initial structure is pursued based solely on syntactic grounds, which, roughly speaking, consist of a few principles (including Late Closure and Minimal Attachment) specifying that the simplest possible structure be built first (e.g., Frazier 1978, 1987; Frazier and Flores D'Arcais 1989).

Under this very bottom-up view, other nonsyntactic information is not considered until after initial structure-building is performed, and then only if an error signal arises to alert the sentence processing mechanism that the constructed structure is inadequate to handle subsequent incoming material. Examples of these other types of material include semantic information such as plausibility (e.g., Ferreira and Clifton 1986) or probabilistic information such as whether a given verb (e.g., *expected*) is more likely to take a noun or a clause as a direct object (e.g., Garnsey et al. 1997; Trueswell, Tanenhaus, and Garnsey 1994; Trueswell, Tanenhaus, and Kello 1993). In other words, this sort of nonsyntactic, more top-down information does not have an effect under this two-stage view until a second stage in which reanalysis is performed (if necessary) and interpretations are generated.

An alternative, so-called single-stage view of sentence parsing is that all possible information sources – morphosyntactic, semantic, probabilistic, contextual, etc. – are computed in parallel. Within this class of "constraint-based" models, the relative influence of each of these various "constraints" on interpretation is calculated incrementally, and new values, or "weights," are assigned to each as more input comes in (e.g., MacDonald, Pearlmutter, and Seidenberg 1994; Tanenhaus et al. 1995; Trueswell, Tanenhaus, and Garnsey 1994), with bottom-up information and top-down information interacting throughout the process. Rather than the parser choosing one syntactic path to follow exclusively, all possible syntactic structures are considered in parallel from the start, ranked according to their likelihood of actually being correct based on the weights of the various constraints in play at the time. As the name of this class of models implies, no reanalysis is required in situations in which errors are recognized. Instead, processing slowdowns are attributed to the system having to reassign weightings to the various information sources, thereby inhibiting the activation, or availability, of the incorrect initial structure and boosting the activation of the correct structure.

A tremendous amount of ink has been spilled in an attempt to adjudicate between serial and parallel models of syntactic parsing, and exploring this vast literature even superficially would exhaust the space allotted for this chapter. An excellent summary of these sometimes contentious studies is provided by van Gompel and Pickering (2007), who point out that whereas some nonsyntactic information sources, such as discourse context, appear to guide the syntactic parser toward initial structures (e.g., Britt 1994; Liversedge et al. 1998; Spivey, Tanenhaus, Eberhard, and Sedivy 2002), semantic plausibility does not appear to (e.g., Clifton et al. 2003; Hoeks, Hendriks, Vonk, Brown, and Hagoort, 2006), and statistical probability (i.e., frequency) may exert such influence, but only under certain conditions or only weakly (e.g., Brysbaert and Mitchell 1996; Kennison 2001; Pickering, Traxler, and Crocker 2000).

A major reason why the rich, dense literature alluded to in the immediately preceding paragraph is not explored more deeply here is that the field of psycholinguistics has begun to move beyond this debate. More sophisticated, integrative models of the architecture of the system subserving language comprehension have recently been proposed, within which a certain degree of modular autonomy is maintained but parallel structure-building along the various levels or paths of linguistic representation is carried out (e.g., Jackendoff 2007, 2011), with frequency (lexical and structural) serving to moderate the computational speed of the various paths. Furthermore, a resurgence of interest in the influence of top-down processing on language comprehension has resulted in computational models of sentence processing that emphasize the role of prediction in language comprehension (e.g., Clark 2013; Gibson, Bergen, and Piantadosi 2013; Hale 2003; Levy 2008; Van Petten and Luka 2012), which may go some way toward explaining why the effects of discourse context, mentioned above, appear to come online so rapidly.

It should be stressed, however, that some degree of prediction has long been acknowledged in the psycholinguistics literature. Consider the sentence in (5), in which the displaced noun phrase (NP) *the car* is associated with the object position of *wanted*. The displaced NP is called the "filler" and the position in the sentence with which the filler is associated is called the "gap."

(5) That's the car that Sophie wanted [gap] for her birthday.

J. D. Fodor (1978, 1989) proposed the active filler hypothesis, to explain why researchers observed that *car* is more active in people's minds at the gap site than at other places in the sentence, and more active than other nouns (e.g., Nicol and Pickering 1993; Nicol and Swinney 1989). The active filler hypothesis also explains why people experience processing difficulty at the potential gap site in (6) once the actual gap site is encountered (cf. Phillips 2006).

(6) That's the car that Sophie wanted [potential gap] her parents to buy [actual gap] for her birthday.

The active filler hypothesis says that the syntactic parser seeks to associate all NPs in non-case-assigning positions with case-assigning positions as soon as possible. In essence, the gap is predicted somewhere downstream as soon as *the car* is encountered. Note, though, that this prediction is tightly linked to syntactic well-formedness requirements – case and thematic role assignment – not strictly because cars are things that people want or buy. Under this syntax-centric view, but not a constraint-based view, we should observe an equal amount of processing difficulty at *wanted* in (6) and in (7) (a comparison which, I believe, has not been directly tested).

(7) It was the typhoid that Sophie wanted [potential gap] to cure [actual gap] quickly.

Predictions about upcoming input based also on nonsyntactic information are receiving more and more attention, often couched in terms of "surprisal" at unexpected incoming material (Hale 2003; Levy 2008). Researchers have speculated for some time that distributional probabilities within language may guide structure-building during comprehension (Elman 1991; Kimball 1975; MacDonald, Pearlmutter, and Seidenberg 1994), but recent advances in "big data" analysis (e.g., Baayen 2008) and computational modeling now allow these probabilistic linguistic tendencies to be explicitly tested as predictors of comprehension (and production). Yet the breadth and precision of predictions that are made during language processing must logically be limited, as it does not seem plausible that we entertain every possible continuation of every sentence at every juncture. As mentioned previously, though, under some circumstances quite specific predictions appear to be made, including the letter order of upcoming words (Luke and Christianson 2012) despite the fact that letter order is often encoded with some degree of flexibility (e.g., Perea and Lupker 2003, 2004). Regarding syntax, Staub and Clifton (2006) show that when readers encounter *either*, they predict the existence of an upcoming *or*. One famous example of evidence that semantic predictions are made, and that disruption of some sort is encountered when those predictions are not borne out, is the N400, which is a brain wave pattern observed in EEG recordings as people read sentences such as *Mary spread the warm bread with socks/butter*. Using this event-related potentials (ERP) method, the N400 has been shown to be reliably larger when the unexpected critical word (*socks*) is encountered compared to a predictable word (*butter*) (e.g., Kutas and Hillyard 1980, 1983).

In all of these cases, predictions about upcoming input are based on previous material (context). Then when the new input is encountered, the degree to which it satisfies predictions can only be determined by checking it against the previous material in some way. As a concrete example, even *socks* in the Kutas and Hillyard sentence above would not be anomalous if we could not remember that we had just read *spread* and *bread*. So the usefulness of prediction in language processing is limited in one direction by countless possible continuations, even in constrained contexts (butter? jam? jelly? honey? Nutella? liverwurst?) (Jackendoff, 2002), and in the other direction by the relatively small capacity of working memory and fallibility of retrieval processes. The limitations that memory places on language processing were demonstrated by Chomsky (1956), who showed that an infinite number of center-embeddings are grammatically allowable in human language (cf. Legate, Pesetsky, and Yang 2014). Yet, despite their grammaticality, more than one center-embedding (e.g., 8–9, from Pulman 1986) becomes nearly impossible to interpret (Chomsky and Miller 1963; Miller and Isard 1963). More recently, several language processing models have provided accounts to explain a number of asymmetries in terms of working memory and/or recall limitations. Perhaps most well known among these asymmetries is the relative difficulty of processing object-relative clauses (11) compared to subject-relative clauses (12).

(8) The woman the man the girl met loved died. (double center-embedding)

(9) The woman the man the girl the dog bit met loved died. (triple center-embedding)

(10) The woman somebody I met loved died.

(11) The horse that the cow frightened ran outside. (object-relative clause)

(12) The horse that frightened the cow ran outside. (subject-relative clause)

(13) The horse that the radio frightened ran outside.

In the interest of space, I highlight only two of these recent memory-based models of language processing. The first was initially introduced by Gibson (1998) as the syntactic prediction locality theory, and later refined by Gibson (2000) as the dependency locality theory. The key insight in both of these theories is that language processing imposes two types of cognitive costs, storage costs and integration costs. Storage costs accrue as elements are held longer in memory; in particular, costs accrue for arguments and their heads, and the longer an argument must be held in memory before being assigned case/thematic role from the head, the greater the cost. Thus, the object-relative clause is harder than the subject-relative clause because the extracted object (*horse*) has to be held in memory while the subject of the relative clause *(cow*) is assigned its case and thematic role by the verb, and multiple center-embedded structures require progressively more storage. Integration costs accrue as more elements need to be integrated at a given point. Again, when the relative clause verb (*frightened*) is encountered in the object-relative clause, both *horse* and *cow* must be integrated, whereas in the subject-relative clause, the extracted subject (*horse*) is already integrated before *cow* is encountered. The latter dependency locality theory was proposed to account for data observed by Warren and Gibson (2002), who investigated the fact that third-person nouns and pronouns feel intuitively to place more burden on memory than first- or second-person pronouns (compare (8) to (10)). Both versions hinge on structurally defined distance between syntactic dependencies to explain what are, as a class, called *locality effects* – observations that dependent elements are generally processed more slowly when they are separated further from one another.

A different approach to working memory and language processing has been proposed by Van Dyke and Lewis (2003), and Lewis and Vasishth (2005) and Van Dyke (2007), which also accounts for *antilocality effects* – the counterintuitive finding that, under some circumstances, increasing the distance between syntactically dependent elements actually speeds the processing of the latter element (e.g., Vasishth and Lewis 2006). This family of processing theories is collectively known as retrieval-activation accounts or similarity-based interference accounts (or a few other related monikers), and rely on the general principles of activation and decay that have long been used to explain forgetting in memory research (cf. Altmann and Schunn 2012; Anderson et al. 2004; Anderson and Lebiere 1998). The basic idea is that as linguistic elements arrive in the input, their concepts and features (on various levels of analysis) are activated. This activation decays over time, which would be the only problem if language did not contain long-distance dependencies (such as displaced elements). But language does contain long-distance dependencies, so sometimes intervening elements are encountered that share certain features with earlier activated elements. When those earlier activated elements need to be reactivated to be integrated into the structure being built, they are interfered with by more recently encountered elements. Importantly, this interference is proportional to the amount of featural overlap the two elements share. To take a concrete example, (11) is predicted to be harder than (12) because *horse* needs to be reactivated as the object of *frightened*, but *cow* intervenes. Because cows and horses share a great number of syntactic and semantic features, *cow* triggers interference in reactivating *horse*. Under this account, (11) is predicted to be more difficult than (13): whereas both cows and horses can frighten and be frightened (and can both run), radios cannot be frightened (nor can they run), and thus *radio* should interfere less with the reactivation of *horse* than *cow* does. Interestingly, Staub (2010) presents eye movement data from normal silent reading of object-relative clauses that suggest independent effects of predictions (i.e., surprisal; Levy 2008) and memory retrieval difficulty (see also Vasishth and Drenhaus 2011). These data suggest that both processes contribute to the difficulty of processing object-relative clauses, and, by assumption, other difficult structures.

Federmeier (2007) also highlights the coexistence of predictive, top-down processes and integrative, bottom-up processing in the Production Affects Reception in Left Only (PARLO) framework. This framework is predicated on experimental results of ERP, functional magnetic resonance imagery (fMRI), and visual half-field methods, in which words are presented in only one visual field or the other to assess the relative contribution of the left and right brain hemispheres. Federmeier argues the combined data suggest that the left hemisphere operates over more abstract representations of the input, and is also involved in more top-down prediction of upcoming material. The right hemisphere appears to operate over more veridical, concrete representations, and proceeds in a more bottom-up, integrative fashion. Understanding precisely how these types of processing are coordinated across tasks and across comprehenders who differ in their cognitive profiles requires further exploration using combined behavioral and neurophysiological/neuroimaging techniques.

As suggested by the immediately preceding discussion, a greater understanding of the role of general cognitive processes and constraints, such as working memory capacity, verbal fluency, and language/text exposure (e.g., Daneman and Carpenter 1980; Engle 2010; Just and Carpenter 1992; Payne et al. 2014), is emerging (though see, e.g., Caplan and Waters 1999, 2002; Caplan, Waters, and DeDe 2007, for arguments that language processing is not impacted by decrements in more general cognitive abilities). This line of research highlights the role of individual differences in how both bottom-up information and top-down information get integrated during language comprehension (e.g., Christianson et al. 2006; Kim and Osterhout 2005; MacDonald, Just, and Carpenter 1992; Swets et al. 2007; Tanner 2013; Traxler 2009; Traxler et al. 2005). Let us now touch upon these topics in turn as we consider how far the above-referenced work on language *comprehension* takes us in our ultimate understanding of language *interpretation*.

A great deal of psycholinguistic work often uses the terms "parsing" and "processing" interchangeably, and sometimes tosses "comprehension" into the terminological blender, mixing all three together. It would be helpful to more carefully delimit these terms, using "parsing" to refer exclusively to morphosyntactic structure-building and "processing" to refer to the integration of all available information. "Comprehension" should be reserved to refer to the way in which readers and listeners mentally represent the actual content of the input. Finally, "interpretation" can be used to refer to the integration of the comprehended content (or the final mental representation) of the input into the larger context of the discourse and the interlocutors' knowledge of both the immediate situation and the world. Chomsky has taken a rather pessimistic view of the ultimate success in understanding language "interpretation," as defined here. He argues:

> …[It is a problem] to construct an "interpreter" which includes the parser as a component along with all other capacities of the mind – whatever they may be – and accepts nonlinguistic as well as linguistic inputs. This interpreter, presented with an utterance and a situation, assigns some interpretation to what is being said by the person in the situation. The study of communication in the actual world of experience is the study of the interpreter, but this is not a topic for empirical inquiry, for the usual reasons: there is no such thing as the study of everything. (Chomsky 2000, p. 69)

Chomsky is correct in pointing out that it is impossible to empirically control for all of a person's past experiences, summed world knowledge, representation of the mind-state of other interlocutors, and present emotional state to determine, unequivocally, how a given person is at the very moment interpreting a given sentence. What Chomsky implies, therefore, is that only the parser, and its work of parsing input (as defined above), is sufficiently narrow to be empirically studied. On the other hand, it can be forcefully argued that shying away from interpretation, or at least the failure to probe explicit comprehension, fails to provide a clear picture not only of comprehension, but even of the parser itself. Lyn Frazier (1998), in an excellent review of psycholinguistic advances through the end of the twentieth century, argues that "deciding between alternative accounts of syntactic parsing may depend increasingly on an explicit account of how and when the constituents of a sentence are interpreted" (p. 137). Furthermore, says Frazier, developing theories of interpretation can be considered to be "the central task of psycholinguists in the future" (p. 138). What appears to be a rather substantial hurdle on the way to addressing the "central task" of illuminating interpretation is the widespread, generally standard assumption that comprehension is reflected straightforwardly by implicit measures of online syntactic parsing.

As an example of implicit measures of online syntactic parsing, let us consider eye movement patterns. An enormous amount of psycholinguistic research has been carried out examining the way people's eyes move as they read text (cf. Rayner 1998, 2009; Staub and Rayner 2007). As people read, their eyes do not scan smoothly across the text; rather, the eyes proceed in a series of stops (fixations) and jumps (saccades). During the fixations (which average around 200–250 msec), information is processed – information about the material within the range of the current fixation, and some limited information about upcoming material (cf. Reichle, Rayner, and Pollatsek 2003) – and during the saccades (which generally last less than 30 msec), readers are essentially blind. It has been well established that fixation durations are longer when processing more difficult material. Similarly, forward saccades are shorter and more frequent as the difficulty of the material increases, and there are more backward saccades (regressions) when reading bogs down, especially in connection to error signals related to the syntactic parse (e.g., in the context of garden-path sentences) (Rayner et al. 2012).

This link between eye movements and the immediate difficulty of constructing the syntactic parse is so well established, in fact, that it is tempting to assume it to be relatively trivial to connect eye movements with comprehension. As an example of this assumption, consider the following quote from Staub and Rayner (2007: 327): "Because eye movements are a natural part of the reading process, secondary tasks are not needed to make inferences about reading comprehension." Certainly such inferences can be made, but how accurate are they? Consider the garden-path sentence in (14a) and its unambiguous counterpart in (14b) (from Christianson et al. 2001; Ferreira, Christianson, and Hollingworth 2001), which are termed DO/S ambiguities because a noun phrase (e.g., *the baby*) is initially parsed as the **d**irect **o**bject of the subordinate verb (e.g., *dressed*) and subsequently must be reanalyzed as the **s**ubject of the main clause verb (e.g., *spit up*).

(14) a. While Anna dressed the baby that was cute and cuddly spit up on the bed.
     b. While Anna dressed, the baby that was cute and cuddly spit up on the bed.

A number of eye tracking studies have demonstrated that readers have trouble with sentences such as (14a) compared to sentences such as (14b) (e.g., Pickering and Traxler 1998; Slattery et al.

2013). Specifically, fixation durations on the main verb (in this case *spit up*) are inflated in (14a) compared to (14b), and readers regress more in (14a), going back to reread the sentence. Following Frazier and Rayner (1982), both of these signs of disruption are interpreted as signaling that the reader has noticed a problem with the ongoing parse, and the rereading is conducted to reanalyze the parse. Crucially, this revision has been assumed to result in a revised interpretation as well. Yet rereading might not be any more successful than initial reading, or it might only be partially successful, or it might signal much deeper comprehension. In fact, we do not yet know for certain how these online eye movement patterns map onto actual comprehension, defined above as the final semantic representation derived from the input.

We have reason to believe, however, that comprehension is susceptible to a number of influences, which stem from the overarching goal of language processing: to derive a coherent, plausible interpretation (Ferreira and Patson 2007). Evidence that people misinterpret sentences more often and far more systematically than previously suspected comes from many sources. Phillips, Wagers, and Lau (2011) provide an excellent summary of various *grammatical illusions*, in which ungrammaticalities are either produced or not noticed (e.g. (15); see, e.g., Bock and Miller 1991; Eberhard, Cutting, and Bock 2005; Solomon and Pearlmutter 2004).

(15) The key to the cabinets are on the table.

The fact that ungrammaticalities in grammatical illusions are not noticed is curious, given that other syntactic constraints appear to trigger processing difficulty immediately upon encounter, even in young children. An example would be Principle C of binding theory (Chomsky 1981), as seen in (16) (from Crain and McKee 1985), which places constraints on cataphoric coreference.

(16) a. While he_i was eating pizza, Ninja $Turtle_i$ was dancing.
b. *He_i was eating pizza while Ninja $Turtle_i$ was dancing.

Consider again the garden-path sentence in (14a). It has been shown a number of times now that people do not fully recover from the initial misinterpretation that *the baby* is being dressed (Christianson et al. 2001, 2006; Patson et al. 2009; Slattery et al. 2013; van Gompel et al. 2006), despite the fact that they both notice that something is wrong at the point of disambiguation (*spit up*) and make regressive eye movements to re-read these sentences. In fact, Christianson and colleagues have asked participants explicitly in various experiments whether the baby was being dressed or whether the baby was spitting up, and large proportions of participants reported believing both to be true, despite the fact that this interpretation should be ruled out by the syntax. Christianson et al. (2006) additionally found that older adults with less working memory capacity were only at chance in believing that *Anna* was dressing herself (as the syntax stipulates). As such, this sort of misinterpretation appears to be a variety of grammatical illusion, in that despite disruption at the point of disambiguation, people apparently forge ahead with a plausible yet structurally illicit interpretation.

One possibility for both grammatical illusions and more general misinterpretation effects is that people are uncertain about the previous material that they have encountered (e.g., Levy et al. 2009). Another possibility, discussed above, is that the language processor balances structure-building (parsing) with meaning-making (processing) en route to the ultimate goal, interpretation. And, in cases where the structural and meaning-based ouputs do not converge, one is chosen over the other without concomitant revision of the other output. The full range and implications of these possibilities have not been thoroughly explored as of yet, but they can be classified as "underspecification" or "good enough" accounts (cf., Christianson et al. 2001, 2006; Christianson, Luke, and F. Ferreira 2010; F. Ferreira 2003; F. Ferreira, Bailey, and Ferraro 2002; F. Ferreira and Patson 2007), in that the ultimate interpretation is based on an analysis of the input that is somehow less than certain or complete. This view of language processing is related to the concept of "satisficing" (Simon 1947) in the broader realm of cognitive science.

Interestingly, individual differences in the way people process input that pits syntax against semantics have been observed by a number of researchers using ERPs to monitor brain activity while reading sentences such as (17) from Kim and Osterhout (2005) (e.g., Kim and Osterhout 2005; Kolk et al. 2003; van Herten, Kolk, and Chwilla 2005).

(17) The hungry meal was devouring the kids.

Space limitations prevent a full discussion of these individual differences. Suffice it to say that such sentences elicit from some people in these studies a so-called N400 effect, traditionally associated with semantic anomalies (see discussion above), while from other people, a so-called P600 effect is elicited. The P600 is traditionally associated with syntactic anomalies or errors (Friederici 1998). It thus appears that processing mechanisms might address anomalies either semantically or syntactically, as suggested in models proposed by Kuperberg (2007; Kuperberg et al. 2006) and Bornkessel and Schlesewsky (2006; Schlesewsky and Bornkessel 2006) based on ERP data, and as suggested by behavioral data by, e.g., F. Ferreira (2003) and Christianson, Luke, and Ferreira (2010). Moreover, the strategy that a given individual's language processor applies to any particular challenging input may well depend on the cognitive resources, like working memory and cognitive control, that are available either in general or in response to a particular task (cf. Christianson et al. 2006; Christianson and Luke 2011; F. Ferreira and Patson 2007; Hussey and Novick 2012; Novick et al. 2014; Swets et al. 2007; Tanner 2013; Ullman 2004). The precise mechanisms underlying individual differences in language processing are yet to be determined. It has not yet even been established whether the differences between individuals are stable within individuals over time. Nevertheless, these differences promise to provide insight into the various tensions we have discussed: top-down vs. bottom-up processing, prediction vs. memory retrieval, serial vs. parallel processing, and structure vs. meaning.

One might imagine that recent advances in brain-imaging technology would help answer questions about individual differences and the connection between language and other cognitive capacities. Although technologies such as functional magnetic resonance imagery (fMRI) are extremely promising, and have yielded intriguing results, continuing disagreements about methodologies and data analysis and interpretation make it difficult to draw firm conclusions just yet. Let us briefly consider two cases in point.

First, fMRI has been used to investigate the field-defining question of how language interacts with more general cognitive functions. Paul Broca (1861) first identified the left inferior frontal gyrus (LIFG) as being involved in language, specifically in syntactic processing. A robust debate still rages, however, about whether this and associated brain regions have language-specific functions (Fedorenko, Behr, and Kanwisher 2011; Fedorenko and Thompson-Schill 2014) or more domain-general functions, such as cognitive control (January, Trueswell, and Thompson-Schill 2009; Novick, Trueswell, and Thompson-Schill 2005) or phonological short-term memory (Rogalsky and Hickock 2011), that are recruited for language processing. The basic approach taken in these investigations is to administer to participants linguistic and nonlinguistic tasks of various sorts while participants are in an fMRI magnet. Then brain regions traditionally associated with linguistic processing are examined for activation during the various tasks. When areas of activation overlap across linguistic and nonlinguistic tasks, it is inferred that the area is performing computations that are involved in, but not unique to, language processing. As noted, however, differences in opinion about the significance and type of overlap, and the components of any given task, have proved to be stumbling blocks on the path to broad consensus.

Another intriguing recent finding related to how language interacts with the rest of the brain is that the left premotor cortex, which is involved in generating sensory-motor representations of physical actions, shows similar patterns of activation when both observing physical actions such as biting a peach and also reading phrases such as *biting the peach* (Aziz-Zadeh et al. 2006). This finding is interpreted within the theory of embodied cognition (e.g., Barsalou 1999; Glenberg and Kaschak 2002; Zwaan 2004), which posits that language comprehension (and various other aspects of cognition) is grounded in our kinesthetic experience with the world (see also the much older motor theory of speech perception, e.g., Liberman and Mattingly 1985). The basic idea is that a class of neurons called mirror neurons, found in the premotor cortex of primates, fire when monkeys (and humans, according to the theory) perform a task or see it performed. In humans, the proposal is that these mirror neurons also fire when hearing or reading about physical actions, and we derive the meaning of these words from this shared firing. In other words, we know what *kick* means because we know how to kick. Of course, human semantics encompasses far more types of meaning than physical actions, and researchers have sought to connect mirror neurons in the sensorimotor and limbic systems to the semantics of perception and emotion (Pulvermüller 2013). Here, too, however, we are yet far from consensus, as other researchers dispute the centrality of mirror neurons in language processing (e.g., Lotto, Hickock, and Holt 2009).

4 Developmental Psycholinguistics

One of the most basic, defining questions in both linguistics and psycholinguistics is how children come to acquire and use language. Accordingly, there is a long history of empirical investigation into how children process language at all levels of analysis. A primary concern of this research has been to determine whether the language processing of young children differs from that of adults, and, if so, how. The logic behind this question is as follows: By removing the vagaries of experience, we can reduce individual differences deriving from that experience, and thus where children and adults show similar processing, we can attribute it to innate or hardwired underlying mechanisms. See Chapter 19 for more detailed discussion.

Of course, it is not a trivial task to assess the language processing and comprehension of children, ranging in age from early elementary school down to newborn. A number of clever methods have been devised to elicit behavioral data from which internal processing states can be inferred (e.g., Hoff 2012; McDaniel, McKee, and Cairns 1996). These include the *high amplitude sucking* paradigm, in which infants are given a non-nutritive nipple with a pressure transducer inside to suck on as they are played recordings of various linguistic input. As the recordings become tedious, the sucking rate slows; when the recording changes, the sucking intensity might or might not also increase. If it does, it is taken as evidence that the infant was sensitive to the change. A similar idea underlies the *conditioned head turn procedure*, which is used with older infants who have better control of their gaze directionality. Audio recordings are played in concert with rewarding visual stimuli, which appear when the audio changes in some theoretically interesting way. Infants begin to associate these pairings and anticipatory head turns are taken as evidence of recognition of the given change. Similarly, the *intermodal preferential looking paradigm* and *looking-while-listening procedure* both pair pictures or video recordings depicting two actions (say, Big Bird tickling Cookie Monster in one video, and Cookie Monster tickling Big Bird in the other video) and an audio recording such as *Big Bird is tickling Cookie Monster. Where is Big Bird tickling Cookie Monster?* (Hirsch-Pasek and Golinkoff 1996). The infant's or young child's gaze is monitored to assess the speed with which the child turns toward the picture or video matching the audio as well as how long the child looks at the correct video.

The reader is encouraged to refer to more comprehensive compendiums of developmental psycholinguistics and language development research (e.g., Hoff 2012, 2014; Jusczyk 1999; McDaniel, McKee, and Cairns 1996; Seidl and Cristiá 2012; Trott, Dobbinson, and Griffiths 2004; Werker, Yueng, and Yoshida 2012), as we are limited here to but a small sample of this fascinating work. For example, newborns between 0 and 5 days old have been found to distinguish between the sounds of different languages (Byers-Heinlein, Burns, and Werker 2010), including the two languages spoken by their bilingual mothers. At just two months of age, English-learning infants can already distinguish between allophonic variations in minimal pairs such as the /t/ in "night rate" and "nitrate" (Hohne and Jusczyk 1994). By about the age of ten months, infants appear to have developed preferences for the phonemic contrasts and allophonic rules of their native (or familiar) language compared to those of other languages, whereas, prior to that age, they appear to entertain all contrasts and allophonic rules allowed in human language (e.g., Jusczyk et al. 1993; Seidl et al. 2009; Werker et al. 2012).

A central focus of much (but not all) of the work examining how very young children process language has been to determine the mechanisms by which children come to have phonological, morphological, lexical, and syntactic categories or rules. In a groundbreaking study Saffran, Aslin, and Newport (1996) demonstrated that eight-month-olds appear to use transitional probabilities between "words" in continuous speech. Saffran et al. played two-minute recordings of three-syllable pseudowords such as (18) (shown with "word" transitions demarcated).

(18) tupiro|golabu|bidaku|padoti|bidaku|golabu|bidaku|tupiro…

After a short pause, they then played a second recording of either the same syllables combined in the same ways as in the first recording (e.g., *tu* always followed by *pi* and *pi* always followed by *ro*), or combined in different ways. They found that infants who were played the recording containing the new combinations listened longer than those who were played the familiar recording. The inference was that the new combinations captured the infants' attention as they worked on learning the new transitional probabilities between the syllables.

This result and many like it – results that have shown that children are able to utilize probabilistic regularities in the input in their language learning – have been taken by some as evidence against the innateness of language and Universal Grammar (e.g., Chomsky 1959, 1975); however, as argued by Yang (2004), statistical learning like this is not at all inconsistent with innateness or Universal Grammar. Furthermore, it seems that computer models of purely statistical learning are significantly improved when bolstered by other learning principles or strategies (e.g., McMurray, Aslin, and Toscano 2009; Swingley 2009; Werker et al. 2012; Yang 2004) that are available to infants.

Infants also use syntactically sophisticated probabilistic information to learn the meanings of new words. For example, infants use the subcategorization frames of verbs (e.g., whether they are transitive or intransitive) to learn their meanings (*syntactic bootstrapping*, e.g., Gleitman 1990; Gleitman et al. 2005; Naigles 1990). Recent studies have shown that children between 19 and 21 months old can use the number of nouns in a sentence to establish the subcategorization frame, and consequently interpretation, of novel verbs (Yuan, Fisher, and Snedeker 2012). The mechanisms underlying infants' ability to map words on to scenes and then attach meaning on to those words are still a matter of considerable debate. Although it is possible that infants store vast statistical information about the co-occurrence of words and entities in the world, it is also the case that the world is a very busy, messy place, and the accuracy of word–world mappings (and associated word learning) decreases considerably once scenes become more complex (Scott and Fisher 2012).

EEG and certain brain imaging techniques (magnetoencephalography, or MEG) can also be used on relatively young infants. Space limitations preclude even a cursory discussion of these studies, however. Suffice it to say here that these methods promise continuing insights into the sophisticated analysis of incoming linguistic input that is performed by even prelingual infants. For example, Kooijman, Hagoort, and Cutler (2005) show that infants quickly and efficiently extract familiar words from connected speech, even in the absence of any semantic association for these words (i.e., words the infants have heard but do not yet know the meanings of). Once some semantic associations are established, however, it appears that 12 to 18-month-old infants' brains are activated differently by familiar words compared to novel words and nonwords (Travis et al. 2011). Moreover, the activation occurs in infants in the same areas of the brain and along similar time courses as in adults. Finally, when comparing the syntactic processing of children to that of adults, what appears to differ between the two groups is the development of cognitive control, rather than access to morphosyntactic principles. Across the few typologically distinct languages that have been examined, it seems to be the case that four- to five-year-old children have more difficulty than adults using later-arriving information (be it structural or lexical information) to recover from initial misinterpretations (Choi and Trueswell 2010; Trueswell and Gleitman 2007; Trueswell et al. 1999). This series of results once again points to the importance of individual differences at the interfaces of language and other cognitive capacities.

5 Applied Psycholinguistics

Although the term "applied psycholinguistics" can refer to several fields, we limit the discussion here to second/foreign language processing. It is only recently that a truly psycholinguistic theory has been developed for language processing by non-native speakers. A major reason for this is that second language acquisition research has historically been concerned with the practical issue of improving foreign language pedagogy or with the broader theoretical issues of whether native and non-native languages were represented the same way in the mind and whether non-native language learning was constrained by Universal Grammar (e.g., Larsen-Freeman, Long, and Jiang 1991; White 2003). In 2006, Clahsen and Felser (2006a, 2006b, 2006c) proposed the *Shallow Structure Hypothesis* (SSH), which effectively reoriented second language researchers toward a more psycholinguistic approach.

What Clahsen and Felser proposed in the SSH was this: It has been observed that even advanced non-native speakers produce certain perseverative errors when they speak or write in their second languages (L2), and furthermore, certain grammatical errors are often not noticed when listening or reading in an L2. This observation about real-time (online) processing stands in stark contrast to the fact that in offline tests of explicit grammatical knowledge, these same L2 speakers often display full conscious command of these very same grammatical principles. The SSH says that the problem is in the real-time processing of the L2, rather than in the underlying knowledge of the L2 (which had been the focus of much of the past decades of L2 research). Clahsen and Felser proposed that non-native speakers are generally incapable of applying the grammatical principles that they know in real-time during processing.

The SSH has spurred a tremendous amount of research testing its claims. Some has provided evidence in support of the SSH and some against (e.g., Clahsen et al. 2010; Felser and Roberts 2007; Felser et al. 2003; Foote 2011; Frenck-Mestre 2005; Havik et al. 2009; Hopp 2006; Jiang 2004, 2007; Lim and Christianson 2013a, 2013b, 2014; Marinis et al. 2005; McDonald 2006; Papadopoulou and Clahsen 2003; Tokowicz and Warren 2010; Williams 2006). As one might imagine, the jury is still out as to the precise strengths and weaknesses of the SSH. The crux of the debate at present is whether L2 processing is qualitatively different from L1 processing, or quantitatively different. Additionally, whatever the answer turns out to be, there is a further question of whether or not it must necessarily differ. The distinction between parsing and processing discussed above might be useful in evaluating the results, and in designing future studies. Is the question whether non-native speakers *parse* L2 input differently from native speakers? Or is the question whether they *process* L2 input differently? If parsing is the issue, then it means that the grammatical constraints of the L2 are not being applied adequately in real-time. But if the grammatical constraints of the L2 are being adhered to and applied appropriately to the input, then processing is the issue, and the observed errors derive from inadequate integration of syntactic and semantic/pragmatic information. Some recent research seems to show evidence of a full morphosyntactic parse coexisting with evidence of semantic misinterpretation (e.g., Lim and Christianson, 2013a, 2013b), but much more work is required to evaluate these theoretical possibilities.

Applied psycholinguistics is a field wrought with complications. Unlike developmental psycholinguistics, in which research subjects (infants and children) are considered to be relatively homogeneous and limited in their experience, adult L2 speakers vary in myriad ways, including age, education, first language (L1), literacy level (in L2 and L1), L2 proficiency level, working memory capacity and other cognitive capacities, etc., etc. Perhaps this is why earlier applied psycholinguistic research rarely utilized the same methods as psycholinguistic research with monolinguals (e.g., eye-tracking, ERP, brain imaging). Recent adoption of linear effects modeling in psycholinguistic data analysis (e.g., Baayen 2008; Baayen, Davidson, and Bates 2008; Jaeger 2008), however, allows for inclusion of these many factors in experimental designs and analyses, accounting for even widely divergent individual differences, which may turn out to be more influential than crosslinguistic differences (Kim and Christianson 2013; Tanner 2013).

Given that most of the world's population is at least bilingual (Grosjean 2010), it is a welcome development in psycholinguistics that bilinguals and adult language learners are no longer treated as deviant or special cases in comparison to monolinguals. We have barely touched upon a couple of important issues in this area of psycholinguistics here; the interested reader is encouraged to refer to Grosjean and Li (2012) and Grosjean (2008) for reviews of the multifaceted literature. As we learn more about individual differences even among monolingual speakers, the interfaces between language and various other cognitive functions are coming more and more to the forefront of psycholinguistic research. Whereas once variability in language processing was regarded largely as noise in the data (but cf. Just and Carpenter 1992), now this variability is becoming appreciated as valuable indication of the exogenous and endogenous constraints placed on language comprehension and production in real-time language use. And conversely, we are beginning to more fully appreciate how language processing also shapes and hones the cognitive capacities with which it interfaces (e.g., Bialystok and Barac 2012; Bialystok, Craik, and Freedman 2007; Fausey and Boroditsky 2010, 2011; Senay, Albarracín, and Noguchi 2010; Zwaan and Radvansky 1998). It is a clearer understanding of these interfaces that promises to dispel the "tensions" considered in this chapter, as well as to alleviate tensions between the related fields of linguistics and psychology.

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