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# Natural pedagogy

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**We propose that human communication is specifically adapted to allow the transmission of generic knowledge between individuals. Such a communication system, which we call 'natural pedagogy', enables fast and efficient social learning of cognitively opaque cultural knowledge that would be hard to acquire relying on purely observational learning mechanisms alone. We argue that human infants are prepared to be at the receptive side of natural pedagogy (i) by being sensitive to ostensive signals that indicate that they are being addressed by communication, (ii) by developing referential expectations in ostensive contexts and (iii) by being biased to interpret ostensive-referential communication as conveying information that is kind-relevant and generalizable.**

## Communicating knowledge

Learning involves acquiring new information and using it later when necessary. Thus, any kind of learning implies generalization of the originally acquired information: to new occasions, new locations, new objects, new contexts, etc. However, any piece of new information that an organism perceives is episodic and particular: it involves a single time, a specific location and context, and particular object(s). The question of how one can learn (i.e. acquire general knowledge) from bits of episodic information is known as the induction problem and has been tackled by various theories of learning. These usually rely on statistical procedures that involve sampling multiple episodes of experience to form the basis of generalization to novel instances. There is, however, a unique way to acquire generic knowledge from a single instance of information intake, namely, when it is transmitted through human communication (see also Ref. [1]). If I point at two aeroplanes and tell you that 'aeroplanes fly', what you learn is not restricted to the particular aeroplanes you see or to the present context, but will provide you generic knowledge about the kind of artefact these planes belong to that is generalizable to other members of the category and to variable contexts. Moreover, the transmission of such generic knowledge is not restricted to linguistic communication. If I show you by manual demonstration how to open a milk carton, what you will learn is how to open that kind of container (i.e. you acquire kind-generalizable knowledge from a single manifestation). In such cases, the observer does not need to rely on statistical procedures to extract the relevant information to be generalized because this is selectively manifested to her by the communicative demonstration. Such a 'short-cut' to generic knowledge acquisition relies heavily on the communicative cooperation and epistemic benevolence of the communicative partner.

Here, we propose that human communication is specifically adapted to fulfil the function of transmitting generic knowledge between individuals (see Box 1 on non-human animals). This is, of course, not the only function that human communication serves: people also communicate about important episodic matters to aid their cooperation [2], to manipulate each other [3], to gossip [4] and for other reasons. Our point is, however, that the minimal cognitive system that could sub-serve episodic communication would not be sufficient to support transmission of generic knowledge without further specific dispositions that motivate experts to manifest, and prepare novices to receive, generic (or, at least, generalizable) knowledge by communication.

We have speculated that communication of generic knowledge was selected for during hominin evolution as a consequence of the emergence of recursive tool making practices, which confronted the observational learner with cognitively opaque contents to acquire. This resulted in a new type of learneability problem for existing observational learning mechanisms, and endangered successful inter-generational transmission of valuable novel skills and innovative practices [5,6]. A new type of communicative learning system based on ostensive-referential demonstrations of knowledge could by-pass this problem by having the expert user actively guide the novice by selectively manifesting the information to be acquired and generalized [7]. Clearly, the most likely beneficiaries of communication of generic knowledge are children, who are always novices with respect to the accumulated knowledge of their culture. This is why we call the specific aspects of human communication that allow and facilitate the transfer of generic knowledge to novices 'natural pedagogy'.

## Receptivity to natural pedagogy

Adults tend to actively facilitate their children's learning by communicative means [8], although the frequency and the manner of such teaching practices varies widely across cultures (Box 2). Children also learn from adults by unguided observation and overhearing, but whenever they are directly targeted by ostensive demonstrations, their pattern of learning changes fundamentally. For example, studies on imitative learning show that children primarily imitate causally efficacious means to achieve goals, and ignore apparently unnecessary actions unless the demonstrator makes it manifest for them that these cognitively opaque aspects are relevant [9–12]. A recent study tested directly whether toddlers interpret action demonstrations as communicative manifestations [13]. When children are shown an action performed in a particular style leading to a clear end state (e.g. a mouse is hopping across the table into

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**Box 1. Is natural pedagogy unique to humans?**

There are many types of social learning mechanisms in the animal kingdom, and they all involve some form of observational learning, in which the observation of an adaptive behaviour of another individual makes it more likely that the observer will produce the same or similar behaviours in the future. In this sense, social learning represents transmission of general knowledge or skills from one individual to another.

Although rare, evidence indicates that certain forms of teaching can also be found in non-human animals. For example, Thornton and colleagues [39] found that adult meerkats supply young pups with dead, disabled or intact scorpions according to the perceived prey-handling ability of the pup, and that such practices are costly for the teacher and help the pupil to learn how to kill scorpions. Such examples of 'opportunity teaching' satisfy the conventional criteria of teaching in non-human animals [40], and demonstrate that not only human adults can have an active role in the learning of their young.

It is also the case that there are many forms of animal communication, and some of them arguably share some features with human communication. For example, although most examples of non-human communication serve the direct interest of the communicator (agonistic displays, territorial or dominance assertions, courtship rituals, etc.), others represent instances of information donation [41], in which the sender's gain is not direct or not as much as that of the receivers (e.g. food and alarm calls). Animal communication can also be referential in the sense of being 'about' some episodic information: such as specific food location (e.g. bees' dance) or predator approach (monkey alarm calls).

However, we know of no examples of communication that would transmit generic knowledge about kinds between individuals in non-human species. Rare anecdotal reports indicating tool-use demonstration in chimpanzees [42] have not been confirmed by others. Similarly, the suggestion that the transfer of novel food items from adults to infants in cooperative breeder primate-species teaches the young about the edibility of food kinds [43], has not been supported by experimental evidence [44]. In other words, although non-human animals communicate about episodic, non-generalizable information (that applies only in the 'here-and-now') and learn new skills by observation or scaffolded individual learning [39], they do not seem to use communication to pass on generalizable knowledge to others. Thus, although the hypothesis that natural pedagogy is a hominin adaptation would not be refuted by the occurrence of a similar social communicative learning mechanism in other species (as analogous adaptations can emerge independently in distinct lineages), the empirical evidence presently available indicates that it is, indeed, a uniquely human phenomenon.

**Box 2. Is natural pedagogy universal in human cultures?**

It is a widespread belief among anthropologists that teaching children is a Western practice that does not exist in traditional societies. For example, Henrich [45] asserts that 'In most small-scale human societies there is very little active teaching', Fiske claims that 'Children learn most of their cultures on their own initiative, without pedagogy' (A. Fiske, unpublished), and even psychologists agree: 'In observation studies of everyday interaction between children and caretakers, relatively little sign of overt teaching was found' [46]. If this is true, natural pedagogy is not universal, not 'natural' and it would be a mistake to consider it as an evolutionary adaptation.

However, we have reasons to doubt the validity of this belief – as long as it is applied to the kind of teaching that natural pedagogy is hypothesized to implement. According to Whiten [47], no examples of teaching were found in rural Nigeria, but he also reports that caretakers sometimes demonstrate for infants how to perform certain acts, and frequently reveal information about object properties for them. (Importantly, no comparable behaviours were found in a gorilla mother [48].) In a monograph on the development of Kpelle children, Lancy [49] concludes that 'parents influence children by example ... but not through direct teaching', but lists numerous observations of direct demonstrations, training, apprenticeship and feedback given to children practising difficult skills, and even cites his informants saying, 'We will teach our children our work'.

This discrepancy between general claims about the absence of teaching and the actual reports is likely to reflect the enormous differences between teaching in Western societies and in more traditional cultures. It is not just that Western education relies heavily on formal schooling, but also that it aims to provide verbal explanation and justification for what is being taught. Transmitting such 'theoretical' knowledge, and regular coaching by instructions, are indeed very rare in traditional societies. However, when assessing the occurrence of pedagogical practices in various cultures, the baseline should not be Western societies but non-human animals (Box 1). In this comparison, natural pedagogy (i.e. transmitting generic knowledge by communication) seems to be universal. This is further supported by recent analyses of archaeological data indicating that the fidelity of transmission and stability of long-term maintenance of patterns and traditions of craft would be difficult to explain without assuming some amount of pedagogical activity in ancestral societies [50].

a house), they tend to reproduce only the end state (put the mouse into the house), often ignoring the manner of action (hopping) [14]. However, if the relevant information concerning the end state is communicated to them verbally by the actor before the demonstration ('the mouse lives in the house'), they reproduce the action style more often. They do so because they conclude that the demonstrator's communicative intention cannot be to redundantly present the same information that she has just told them about, and so they identify the manner of action as the new information communicated and to be learnt [13]. Ostensive communication does not only make children pay more attention to the demonstration but they also see it as a special opportunity to acquire generalizable knowledge.

Natural pedagogy is a basic cognitive adaptation, which is indicated by the fact that young infants display receptivity to adults' ostensive communications well before they show evidence of learning from such interactions. Here, we review some recent studies that demonstrate this preparedness in the form of three kinds of early perceptual and cognitive biases: (i) preferential attention for the sources of ostensive signals, (ii) referential expectation induced by ostensive contexts and (iii) an interpretation bias to preferentially encode the content of ostensive-referential communication as representing generalizable knowledge.

## Sensitivity to ostensive signals

Human communication is ostensive: it communicates not just the message destined to influence the targeted recipient but also the very fact that this message is being intentionally communicated to her [7]. Thus, human communication is often preceded, or accompanied, by ostensive signals that (i) disambiguate that the subsequent action (for example, a tool-use demonstration) is intended to be communicative and (ii) specify the addressee to whom the communication is addressed. Because the interpretation of any additional signals might depend crucially on construing the act as communication, sensitivity to at least some of the ostensive signals is most likely to be innate.

The most obvious ostensive signal in human communication is direct gaze towards the addressee, which usually results in mutual eye contact. Newborns prefer to look at faces with direct gaze over faces with averted gaze [15],

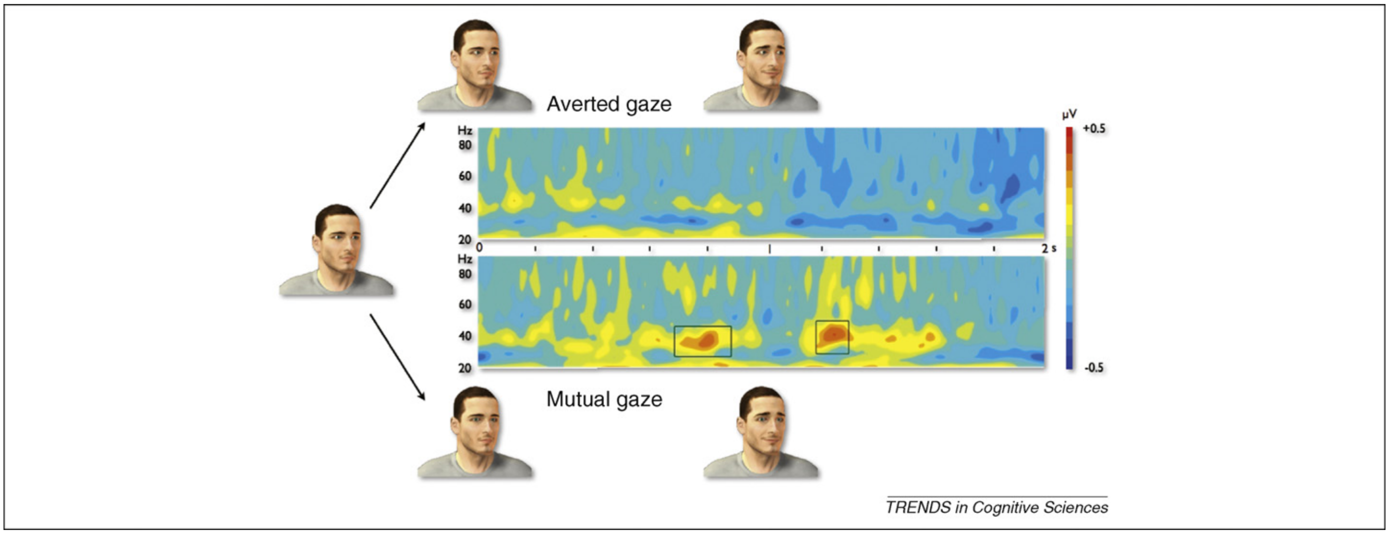


**Figure 1**. 4-month-old infants' brain responses to dynamic mutual and averted gaze stimuli [21]. These time-frequency plots depict gamma-band electroencephalographic (EEG) oscillatory activation at right fronto-polar sites in response to a gaze shift directed away (top row) or towards (bottom row) the infant (at 0 s), and in response to an eye-brow raise together with a smile (at 1 s). Note that the two ostensive-communicative signals elicit the same activation, and that the infant brain responds to the smile only if it follows mutual gaze (i.e. when it is addressed to the viewer).

even if these are schematic face-like patterns [16]. Further results indicate that what newborns are looking for is the prototypical eye-contact stimulus. First, their preference for direct gaze disappears with upside-down faces [16]. Second, newborns' (and adults' [17]) preference for upright over upside-down faces is eliminated when the contrast–polarity relation that is characteristic to human eyes (dark iris on the background of white sclera [18]) is reversed [19]. Recent neuroimaging studies provided evidence that 4-month-olds interpret dynamic eye-contact as an ostensive signal: (i) similar neural structures are activated by direct gaze as found active in adults [20] in response to communicative signals and (ii) the same neural responses are produced by two different facial signals (direct gaze and eye-brow raise), both interpreted as ostensive stimuli by adults [21] (Figure 1).

Ostensive signals also exist in the auditory modality. For example, the special intonation pattern of 'infant-directed speech' ('motherese') can make it manifest that a child is being addressed, and could indicate to an infant that she is the intended recipient. Newborns prefer infant-directed to adult-directed speech [22] even if they are born to congenitally deaf parents [23]. Interestingly, parents also modify their actions when they ostensively demonstrate them to infants [24], and infants prefer these 'motionese' versions to adult-directed action demonstrations [25].

## Referential expectation

If infants are prepared to learn generic knowledge when adults address them, they should expect the adult to specify the referent about which she is teaching them. However, preverbal infants do not yet understand linguistic or other symbolic modes of reference, and comprehending iconic signs would require familiarity with referents. Thus, infant-directed communication is initially restricted to the use of indexical reference in the form of deictic gestures, like pointing to or showing objects, or just shifting eye-gaze towards them.

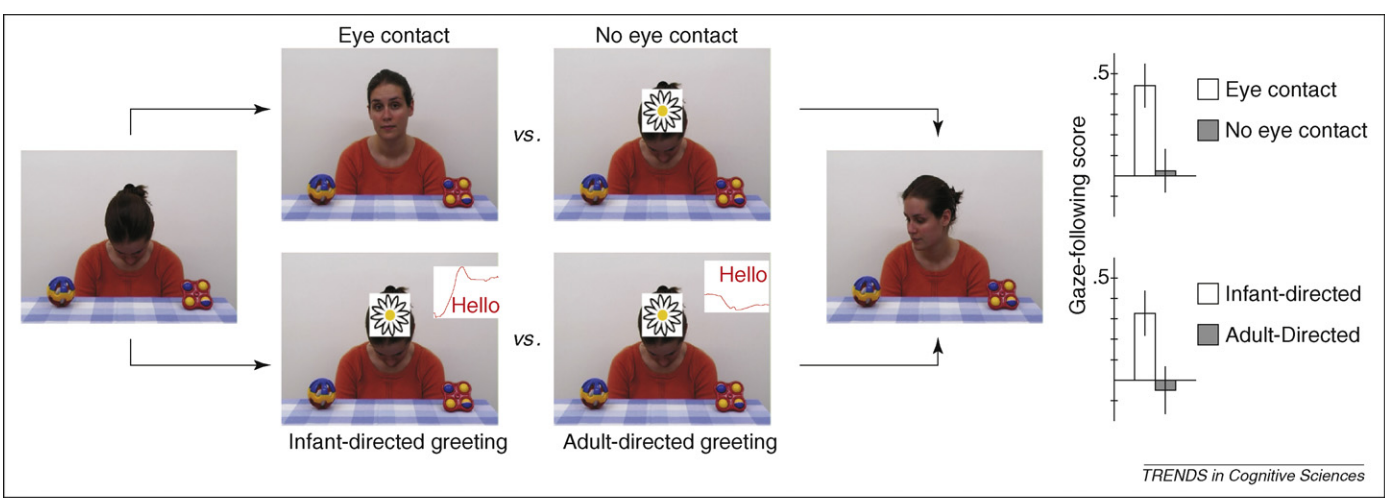


**Figure 2**. 6-month-old infants follow gaze after ostensive signals [29]. If a gaze shift to one of two target objects is preceded by ostensive-communicative signals, such as eye contact (top row) or infant-directed speech (bottom row), infants tend to make their first object-directed saccade (measured by an eye-tracker) to the same object. However, in the absence of such cues, they do not follow the model's gaze. This suggests that early gaze following reflects communicative-referential expectation rather than being a mere reflex.

Infants follow the gaze of interactive partners to identify what they look at from early on [26–28]. Gaze following also exists in other species, and can be explained by the benefit it affords to the individual who is led to sample those parts of the visual environment that others have found worth attending to. In human infants, however, gaze following also serves communication. This is evidenced by the fact that young infants tend to follow gaze shifts only when these are preceded by an ostensive signal such as eye contact or infant-directed greeting [29] (Figure 2). In fact, infants prefer to watch a person making object-directed to non-object-directed gaze shifts, but only if these shifts start from a direct gaze position [30].

A recent study demonstrated that infants expect to find a referent when they follow someone's gaze in an ostensive context [31]. 8-month-olds observed someone on a computer screen ostensively looking at and greeting them before shifting her gaze to look behind one of two barriers. After this, an object was revealed either at the targeted or at the other occluded location. Infants' looking pattern indicated that they expected to find an object at the location where the person's gaze was directed, just like older infants do in similar live situations [32]. Furthermore, if an ostensively communicating demonstrator looks and points behind a barrier while also naming an object using a kind term that is within 13-month-olds' receptive vocabulary ('A spoon! It's a spoon!'), infants of that age do not just expect to find an object there, but an object that belongs to the kind that was named. Crucially, the integration of referential signals is not simply associative, as it does not take place if the two kinds of referential signal (the deictic gestures and the verbal expressions) originate from different sources (when a male person is looking and pointing while a female voice utters the verbal expressions) [33].

**Box 3. Outstanding questions**

- Do the perceptual and cognitive biases of natural pedagogy represent a specialized system of adaptive dispositions for transmitting and learning generic knowledge, or do they reflect more directly the fundamental structural organization of human communication (and of the cognitive architecture that implements it), indicating that its basic design has been adapted to the need of efficient transfer of generic knowledge?
- What is the relationship between the interpretation bias found in infants' expectations about the likely intended contents of communicative demonstrations on the one hand, and children's early understanding of generic speech [51] on the other?
- It is well known that people with autism display a relative indifference towards ostensive and referential communicative signals. Do they also lack the interpretation bias for generalizability that these signals induce in typically developing individuals?
- The behavioural morphology and the functional use of 'marked' forms of communicative expressions during teaching (e.g. Ref. [24]) share suggestive similarities with the phenomenon of pretend play [52]. This raises the possibility that pretend play is a further functional adaptation involving a special form of communicative representational activity that exploits (and is parasitic on) the primary cognitive adaptation for natural pedagogy.
- Although animal communication differs from human communication in many respects (Box 1), there is a non-human species that shows special sensitivity to human communication cues. Does the tendency of dogs to follow human ostensive referential signals represent an adaptation to natural pedagogy or does it serve a different function parasitic on human communication?

## Interpretation bias for generalizability

The results reviewed earlier confirm that infants expect to receive ostensive-referential communication from adults. However, the hypothesis of natural pedagogy goes further and proposes that children expect to learn something generalizable in ostensive-referential contexts rather than just become informed about particular episodic facts that obtain only in the 'here-and-now' (Box 3). This is what distinguishes our hypothesis in the first place from competing proposals, according to which human communication originates evolutionarily and ontogenetically from a basic motive to cooperate with others to achieve shared goals [2].

That infants expect to receive generic information about referent kinds is supported by the finding that, when they observe others' ostensive emotion displays about objects, 14-month-olds are more likely to interpret these as conveying valence information about the referent than expressing the subjective attitude state of the communicator towards the object [34]. In fact, a recent study suggests that 18-month-olds readily generalize the valence information displayed about the referent to other people – as long as this is communicated to them in an ostensive manner [35]. Thus, when they observe someone's attitude expressions in a non-communicative context, they infer the person's particular subjective preference, but do not attach the expressed value to the referent object and do not generalize the displayed object-directed attitudes to other people. By contrast, when the same object-directed attitudes are presented to infants by ostensive communication, they become interpreted as generic valence properties of the objects and are used to predict other people's preferences towards them.

When learning about enduring generic properties of object kinds, infants have to encode them in a way that allows for their later use in identifying other objects belonging to the same kind. The visual features of an object normally belong to its permanent properties (objects do not tend to change their appearance), and therefore are informative when recognizing the same object again or when identifying other objects of the same kind. By contrast, the current location of a moveable and manipulable object is irrelevant for its future recognition (or for the identification of other members of its kind), so location could be regarded as a transient episodic feature that represents no generalizable kind-relevant information. A recent study demonstrates that 9-month-olds are sensitive to this and modify their encoding strategies accordingly when they perceive an object in an ostensive-referential context [36]. Thus, although they are more likely to detect the change of an object's location than its appearance in a non-communicative situation, they show the reverse pattern if the object is perceived in an ostensive context (Figure 3). In fact, they seem to completely neglect the location of an ostensively referred object despite the fact that the referential gesture (deictic pointing) that has identified the object for them did so through specifying its location (Figure 3).

Clearly, such an ostensively induced processing bias that suppresses the encoding of transient episodic infor-

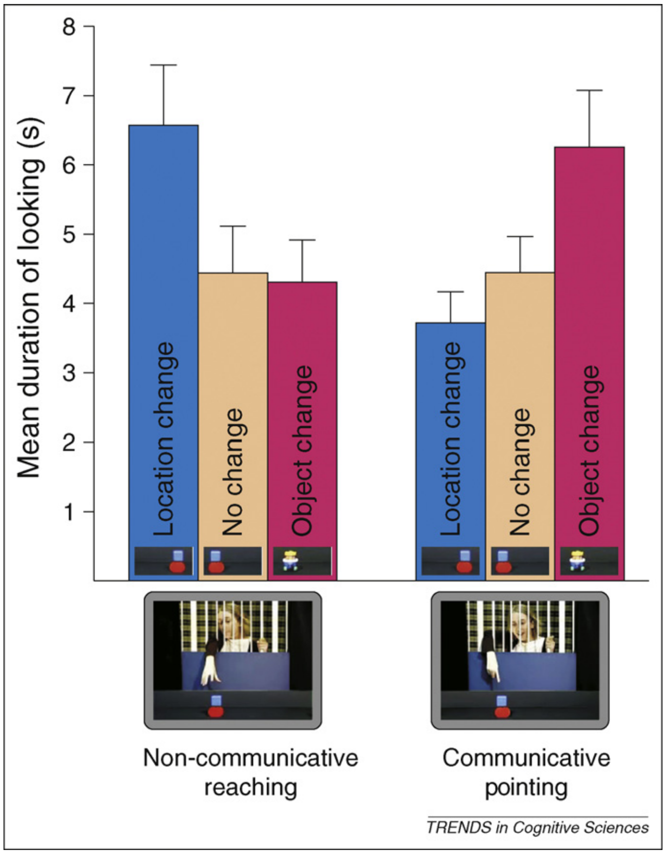


**Figure 3**. Change detection in communicative and non-communicative contexts [36]. 9-month-old infants were presented with an object, which an actor was either trying to obtain (non-communicative reaching) or ostensively communicated about (communicative pointing). After the object was occluded for 5 s, infants detected a change of its location but not of its identity in the non-communicative context, and a change of its identity but not of its location in the communicative context. Thus, ostensive-referential signals facilitate the encoding of enduring object features that are relevant for recognition and generalization at the expense of ignoring transient object locations in preverbal infants.

mation about object location can help focusing the limited resources of infants' attention to enduring and kind-relevant object properties. Under specific circumstances, however, this bias can give rise to erroneous disregard of location information even in contexts (such as an object-hiding game) in which current object location happens to be the pragmatically most relevant information to attend to. We think that this is exactly what happens when infants display the well-known perseverative search error in the classical A-not-B task [37] by trying to find a target object at a location where it had been hidden earlier (in container A) despite the fact that they have just seen it being hidden at a new place (in container B). This error shows that infants ignore the new episodic information about the present location (B) of the object after having seen the adult repeatedly hide the object at a different location (A). Crucially, in the standard versions of the task, the hiding actions are presented in a strongly communicative ostensive-referential context. However, in a recent study using a modified procedure in which these communicative cues were removed, infants' tendency to commit the perseverative search error was robustly reduced [38]. This suggests that a great proportion of the error induced in standard versions of the A-not-B task is because of a pragmatic misinterpretation of the experimenter's hiding actions as a communicative demonstration of some generalizable information (e.g. that container A is 'for' storing the kind of objects being hidden) rather than an interactive hiding–finding game.

## Conclusions

Human children have to learn a large amount of culturally relevant general knowledge to become mature members of their cultural community. This is supported by powerful learning mechanisms that capitalize on innate biases, on statistical regularities extracted from the environment and perhaps even on capacities to construct new representational systems. The evidence we reviewed here indicates that infants are also prepared to learn generic kind-relevant information directly and from a specific source that is not available to other species: from benevolent communicators who manifest generic knowledge 'for' them that would be difficult (if not impossible) to acquire without such support.

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