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Social learning and social cognition: The case for pedagogy

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Abstract. We propose that humans are adapted to transfer knowledge to, and receive knowledge from, conspecifics by teaching. This adaptation, which we call 'pedagogy', involves the emergence of a special communication system that does not presuppose either language or high-level theory of mind, but could itself provide a basis facilitating the development of these human-specific abilities both in phylogenetic and ontogenetic terms. We speculate that tool manufacturing and mediated tool use made the evolution of such a new social learning mechanism necessary. However, the main body of evidence supporting this hypothesis comes from developmental psychology. We argue that many central phenomena of human infant social cognition that may seem puzzling in the light of their standard functional explanation can be more coherently and plausibly interpreted as reflecting the adaptations to receive knowledge from social partners through teaching.

1 Introduction

One way to highlight the merits of a new theory is by making explicit previously largely unnoticed inconsistencies in the standard functional explanations for some of the central phenomena in its domain, and then to demonstrate how the novel theoretical approach can shed new explanatory light on such phenomena successfully resolving the puzzles inherent in their previously accepted interpretations. In what follows, we shall follow this strategy in presenting our new hypothesis on human adaptation for pedagogy. Therefore, we shall start by discussing a few salient examples of early competences in the domain of infant social cognition and show why their standard functional interpretations involve puzzling inconsistencies when one scrutinizes them in the light of the available data.

We shall then outline our new theoretical proposal about human pedagogy as an evolutionary adaptation for efficient knowledge transfer. We shall explicate our theory in three ways: a) by providing a speculative hypothesis – a just-so story – about the possible evolutionary conditions that could plausibly account for the selection of pedagogy as a special type of social learning mechanism, b) by describing the design specifications of pedagogical communication in humans, and c) by reviewing evidence from the developmental psychology of infant social cognition that supports our hypothesis of the existence of this dedicated system of pedagogical knowledge transfer during human ontogeny. This review will reveal how the application of our theory of human pedagogy to the puzzling phenomena of infant social cognition can clear up the inconsistencies that are inherent in their standard functional interpretations. We shall argue that the phenomena in question receive a more satisfactory and coherent alternative explanation when viewed as the results or manifestations of the basic human evolutionary adaptation to receive knowledge from conspecifics through specialized forms of pedagogical interactions.

2 Some puzzles in infant social cognition

2.1 Face preference in newborns

Newborns are more likely to follow, and more persistent in following, geometric patterns that resemble faces than other similar geometric patterns, including upside-down faces (Johnson & Morton, 1991). Newborns also show this preference when presented with static images on the visual periphery: they tend to look first, and longer, at the face-like pattern (Valenza, Simion, Cassia, & Umiltà, 1996). The standard functional explanation for this behaviour is that it reflects an adaptive orientation mechanism that ensures that infants will fixate and learn about the most relevant social stimuli in their environment. This functional interpretation, however, does not explain why newborns' face preference is orientation-specific; in other words, why it is restricted to upright faces. Adults and children perform much better with upright than upside-down faces in face recognition tasks, and this finding can be plausibly explained by the fact that the subjects have had more experience with seeing, and have acquired more expertise in recognizing, upright than inverted face orientation. Newborns, however, see faces, including their mother's face, in many different orientations (importantly, during breast feeding the mother's face does not appear in the canonical orientation). Thus, if the function of newborns' face preference were finding faces around, evolution could have equipped neonates with a more efficient orientation mechanism that could also exploit the opportunities provided by non-canonically oriented faces to find conspecifics and to learn about them. A further relevant aspect of newborns' face preference, which we have recently demonstrated (Farroni, Johnson, & Csibra, unpublished data), is

that it disappears if the contrast polarity of the stimuli is reversed from black-on-white to white-on-black. White spots on a black background form as good of a facial pattern as black spots on white background and could, therefore, also be used successfully to identify conspecifics. Why does not face preference in newborns exploit this possibility either?

2.2 Gaze-following

Our second example of a puzzling standard explanation is the functional interpretation of the phenomenon of gaze following by infants. In the second half of their first year, infants start to look where an interactive social partner is looking at, establishing what is called a joint-attention situation with the adult (Moore & Dunham, 1995). In fact, in laboratory situations, younger infants and even newborns also tend to look in the same direction as the eyes of a face in front of them have moved moments before (Hood, Willen, & Driver, 1998). The standard explanation for this behaviour is that the eyes provide privileged access to the mind of others: looking at the gaze target of another person will inform the infant about what the other person is attending to, and allows him to share her experience. The problem with this functional interpretation is that infants are hopelessly inaccurate in locating objects targeted by the gaze direction of others (Butterworth & Jarrett, 1991). In well-controlled laboratory experiments, young infants manage to identify the object the other is looking at only in the simplest situations (for example, 6-month-olds, who turn their gaze towards the general direction of the other's visual focus, will stop at and explore the first salient object found in that direction irrespective of whether that is the actual target of the other's gaze or not), and it is not until they are about 18 months old that they can accurately zero in on the target of the other's attention. This, however, implies that in real-life situations infants will be much more likely to mistakenly identify the object of the other's attention than to succeed in sharing her mental experience. How could the hypothesized function of mental sharing be facilitated by being engaged in a behaviour that would regularly mislead the child about the other's attentional focus? And how could the frequently resulting misattributions help the development of understanding others in terms of mental states?

2.3 Imitation of novel actions

In a classic study, Meltzoff demonstrated to 14-month-old infants a rather unusual action: he bent forward from waist and lit up a box by touching it with his head (Meltzoff, 1988). A week later the infants came back to the laboratory and most of them spontaneously performed the same action: they touched the box with their head. Why? According to the standard functional explanation, imitation allows the child to learn how to achieve certain goals, for example new and interesting effects, like lighting up this box (Tomasello, 1999). This explanation is puzzling, however, because infants do not need to imitate to achieve this goal. They do not have to imitate the novel head action, because they have a simpler means at their disposal to bring about the same end: they could simply touch the box with their hand. Why do they imitate then?

3 The 'pedagogy' hypothesis

The puzzle in all three phenomena lies in a mismatch between the assumed function and the characteristic pattern of infant behaviour it purports to explain. The behaviour is either suboptimal with respect to the attributed function (as in the case of newborns' face preference), or is simply unnecessary to fulfil it (as with imitation), or it can downright defeat its stated function (as in gaze-following). Here we propose a hypothesis that attempts to resolve these puzzles. The hypothesis simply states that humans are adapted to transfer knowledge to, and receive knowledge from, conspecifics *through teaching*, and we claim that these phenomena, as well as many other central phenomena of early social cognition, reflect this adaptation.

We are, of course, not the first to realize the importance of teaching in the evolution and ontogenesis of human cognition; several theorists have pointed this out before (e.g., Barnett, 1973; Caro & Hauser, 1992; Kruger & Tomasello, 1996; Premack, 1984; Premack & Premack, 2003; Tomasello, Kruger, & Ratner, 1993; Tomasello, 1999). Nevertheless, our proposal differs from those of others in at least two significant respects.

First, teaching is usually described as a secondary derivative of some more fundamental human-specific adaptation, like language (Dunbar, 1996), theory of mind (Tomasello, 1999), aesthetics (Premack & Premack, 2003), or culture itself. In contrast, we believe that the ability to teach and to learn from teaching is a primary, independent, and possibly phylogenetically even earlier adaptation than either language or the ability to attribute mental states. Having language and a theory of mind would no doubt assist both teaching and learning from teaching but, as we shall argue, they are not necessary prerequisites for pedagogical knowledge transmission. On the contrary, it seems to us equally possible that the cognitive mechanisms that had independently evolved to support pedagogy may have contributed to the subsequent evolution of language and theory of mind.

Second, while several theorists have developed specific proposals about what abilities a 'teacher'

needs to successfully transmit cultural information (e.g., Olson & Bruner, 1996; Strauss, Ziv, & Stein, 2002), the complementary cognitive mechanisms that make someone able to benefit from teaching have so far been largely ignored (for an exception, see Tomasello, Kruger, & Ratner, 1993). In fact, there is a long history of discussing the facilitative effects of cultural environment on early human social and cognitive development in terms of 'scaffolding' (Wood, Bruner, & Ross, 1976; Whiten, 1999). These approaches are typically based on the implicit assumption that what is 'scaffolded' by parents' educational practices is the child's general-purpose learning mechanisms. In contrast, we propose and emphasize that human parental inclination for manifesting cultural knowledge in teaching contexts is complemented by dedicated cognitive mechanisms on the infant's part that ensure that he will benefit from his parents' teaching efforts.

4 Just a just-so story

As our hypothesis asserts that pedagogy is a primary human-specific adaptation that does not necessarily rely on other (arguably human-specific) abilities like language or theory of mind, the question of evolutionary origin would inevitably be raised. How and why did pedagogy evolve? Because of the scarcity of hard facts about human cognitive evolution, any attempt to reconstruct pre-historic history would necessarily be a 'just-so story'. Nevertheless, whenever evolutionary adaptation is claimed to play a role in human cognition, it is important to demonstrate that there exists at least one story (even if it is a just-so story) that could plausibly explain the emergence of the new trait/behaviour/cognitive mechanism. Below we shall outline our admittedly just-so story that puts pedagogy in an evolutionary context, relates it to the emergence of other cognitive abilities, and drives our intuitions about the possible phylogenetic conditions that could have provided selective pressure for the evolution of this dedicated cognitive system.

4.1 'Simple' teleology

Our story starts with early hominids, who, just like some primate species living today, most notably chimpanzees, occasionally resorted to using tools. Simple tool use certainly requires the understanding that a given object is 'good for' achieving a specific goal. However, 'seeing' the object in terms of its goal-related affordance properties is being maintained only until the goal is achieved (or abandoned). In fact, chimpanzees tend to choose functionally suitable objects from the immediate surroundings as temporary tools to achieve a specific goal. Sometimes they even modify them on the spot to improve their affordance properties to enable them to harness the concrete goal in the situation. However, after having used the object to attain their goal, they tend to simply discard it and move on. This can be considered evidence for a goal-activated, situationally restricted and temporally fleeting 'teleological mode' of object construal. It does not imply a more permanent categorization of such objects *as* tools or representing them as having stable functional properties.

4.2 'Inverse' teleology

We know though that our ancestors have surpassed or qualitatively modified their 'simple' teleology already several million years ago, when they started to view the tools that they created as having *permanent functions*. As evidenced in the archaeological record, this new level of more stable teleological conceptualization of objects *as* tools was manifested in routine behaviours such as keeping tools instead of discarding them after use, storing them at specific locations, or pre-fabricating the tools at one location and carrying them for long distances for later application at a different place. We suggest that this momentous change in the application of teleological reasoning about tools required a *reversal of perspective* in the way our ancestors were thinking about tool-goal relations. While 'simple' teleology, being always triggered by the activation of a desire for a concrete goal, raises the question, "Which object could I use to achieve this specific goal?", 'inverse' teleological reasoning is triggered when the sight of an object activates the question: "What purpose could I use this object for?"

4.3 'Recursive' teleology

By allowing tools to be conceived of as desirable goals, 'inverse' teleology opened up the way to attaching functions to tools that did not directly involve outcomes that enhance the adaptive fitness of the individual (such as food). This, in turn, made it possible to apply teleological reasoning in a 'recursive' manner by looking at objects as potential tools to create desired tools as their goals. Therefore, the emerging ability to conceive tools with useful functions as themselves being the goal objects of desire led to the capacity of thinking in terms of chains or hierarchies of means and ends. The archaeological record, in fact, provides evidence of the early use of tools to make other tools, manifesting the presence of 'recursive' teleological competence early on in hominid history.

4.4 Learnability of 'recursive' tool use

Now, consider the situation that children find themselves in when growing up in a hominid group that has already gone through these transformations of teleological thinking and that relies on tool use

extensively. The children themselves will expect that objects (and especially artefacts) have functions, because they are equipped with the cognitive mechanisms that had been selected to support teleological thinking. How can they figure out the function of an object? First, they can try various actions with it to find out the object's affordances. Human infants (unlike infants of most other primates) are indeed fascinated with objects and enjoy manipulating them. Figuring out artefact functions by such trial-and-error methods, however, is slow and very limited. Trial-and-error procedures would not reveal, for example, functions that have their useful effects through multiple mediations (tool use on tools), or in the future.

Alternatively, they can rely on various social learning mechanisms, from stimulus enhancement through emulation to imitation, that have been observed in many species (e.g., Whiten, 2000). They can observe, for example, when another individual uses a tool, and can infer its function from the visible outcome achieved. However, this kind of observational learning of function is also restricted to simple tool use that leads to immediately interpretable effects, and not easily applicable to mediated tool use that creates tools. This is because any behaviour has multiple effects, and unless the range of desired outcomes is pre-defined, no behaviour is transparent to its goal. If, for example, an individual observes another using a tool to peel away the skin of a hard fruit, it may be obvious that the tool is used in order to get to the edible parts of the fruit and not in order to obtain bits of fruit skin, but this inference is based on a pre-existing knowledge of the desirability of the food, and is reinforced by observing the subsequent consumption of the fruit. In contrast, imagine the child observing someone using a tool to carve away bits of a piece of wood, which results in a smaller piece of wood and shavings (not to mention sound effects etc.). In this case there is no way for the child to know which of these outcomes is the desired effect, and hence the function of the tool, unless he can rely on further pre-existing knowledge about the tool, the material, or the observed individual's immediate goal.

This difficulty does not imply that acquiring tool use by observational learning is impossible. When the actual goal of the behaviour is opaque, one can acquire the use of a tool by *blind imitation* (Want & Harris, 2002), hoping that he will learn later the useful function of the tool. Indeed, humans, and especially human children, tend to imitate apparently meaningless actions much more readily than other species. Imitation is not necessary, however, when the goal of the to-be-learned behaviour and the causal affordance properties of the tool are transparent: in such cases the child can acquire the tool use by emulation (Tomasello, 1996).

Blind imitation, however, solves only one side of the problem. Mediated tool use conceals not only the ultimate goal of the behaviour but it is also opaque with respect to the background knowledge that governs the observed actions. Without this background knowledge, one would not know what conditions are appropriate to use the tool, which aspects of its observed use are essential and relevant, and which are superfluous. A blind imitator runs into the risk of repeating the observed action when it is not appropriate, and replicating many elements of the action that are idiosyncratic to the observed individual or situation, but are irrelevant with respect to the functional use of the tool. Even if one has a good guess about the goal of an action, it does not imply that he would know which elements of the observed actions are relevant for goal achievement, unless he also possesses the whole package of causal knowledge to grasp the connection between action and its effects.

This is the critical point of our story. Generally, the observable behaviour of individuals is never transparent either in respect to the background knowledge that governs their actions or in respect to the ultimate goal of the action (if it were transparent, cognitive psychology would not exist as a scientific discipline). Thus, to acquire the relevant knowledge through observation sets an ill-posed *inverse problem*: a behaviour can always be generated and explained by an infinite number of different mental state combinations, representing diverse goals and/or different types of background knowledge. This difficulty is just multiplied when observing mediated (recursive) tool use, where no perceptible reward would inform the observer about the tool's function and, in the absence of that, there is no way to assess the relevance of any element of the behaviour observed. If at least some information about the immediate goal of the tool user and the knowledge that she applies were made explicit, the observer would have a much better chance to extract functionally relevant knowledge from his observation. This information can only be made explicit by the user himself, the individual who knows both the function and the relevant usage of the tool. If she not just applies but also *manifests* some of this knowledge in her behaviour, and the observer is receptive to these manifestations, knowledge transfer becomes much easier. (This is, of course, not a direct knowledge transfer, and as we shall see, it relies heavily on inferential processes. Nevertheless, these inferences, as we shall argue later, are constrained much more than the inferences one has to use in simple observation.) In case of tool use, manifestation of knowledge may be achieved by demonstrations: emphasizing some, while ignoring other, aspects of tool use, separating products from

by-products, contrasting suitable and unsuitable conditions of use, etc.

In sum, we hypothesize that the "birth of pedagogy" was necessitated by extensive tool use by early hominid groups, and especially by the appearance of mediated tool use generated through 'recursive' teleology that decoupled means and ends in such a way that made these functional aspects opaque and uninferable for the uninformed observer. In fact, proliferation of tool use, and the emergence of rich artefact culture, would have probably been impossible without an efficient social learning mechanism that enabled transmission of not just observable behaviours but also unobservable knowledge. At the same time, as soon as this mechanism evolved, it opened up new territories for evolutionary selection, both in biological and in cultural evolution. First, when the mechanism became available, it could be applied to domains outside tool use as well. In other words, pedagogical knowledge transfer may have extended to knowledge domains that are not strictly related to tool use. Second, the very fact that pedagogical knowledge acquisition can work without observing immediate, or even delayed, rewards gained by the teacher, implies that the relevance of the acquired knowledge is presumed and not verified by the learner. Consequently, it allows for the acquisition of knowledge contents that are not only functionally non-transparent, but that do not seem to (or actually do not) have any direct and perceivable adaptive value at all. This aspect of pedagogical knowledge transmission enables the development, transmission, and stabilization of arbitrary conventions and traditions that are uniquely characteristic of human cultures. Third, pedagogy essentially created a new way of information transfer among individuals through the use of ostensive communication (see later). This might have facilitated or even provided a precondition for the evolution of linguistic communication. And fourth, an active inclination for pedagogical knowledge transfer implies seeing each other not just in terms of kinship, as sexual partners, sources of protection, and members of a social hierarchy, but also as repositories and consumers of knowledge, which might have had profound effects on the further evolution of human social cognition.

Let us emphasize again that the above story is *just* a just-so story. The main body of evidence for our claim that pedagogy is a primary human-specific adaptation comes not from evolutionary history but from developmental psychology. Even if the above historical reconstruction were shown to be flawed, the theory may prove to be the best explanation of the developmental evidence we have.

5 The design specifications of pedagogy

We define *pedagogy* as (1) explicit manifestation of generalizable knowledge by an individual (the 'teacher'), and (2) interpretation of this manifestation in terms of knowledge content by another individual (the 'learner'). In other words, pedagogy, in the sense that we use this term, is a specific type of social learning achieved by a specific type of communication. It is important to realize the distinctive nature of pedagogy both as a particular type of social learning, and as a particular type of communication.

On the one hand, pedagogy, as a form of social learning mechanism – similarly to all types of social learning (imitation, emulation, stimulus enhancement, etc.) – conveys generalizable knowledge that is valid beyond the actual situation. However, unlike most other social learning mechanisms that rely on mere observation, pedagogy requires active participation by the source of knowledge (the teacher), which is achieved by a type of communication involving manifestation of relevant knowledge. The fact that pedagogy requires an active participation by the source of knowledge implies that it may incur costs for the teacher. We would therefore expect that this kind of social learning mechanism, unlike most other types of social learning that predominantly spread behaviours horizontally (Laland, Odling-Smee, & Feldman, 2000), would be selected primarily to support vertical (parent to offspring) transmission of knowledge. Indeed, vertical transmission seems to be the dominant mode of diffusion of cultural traits among humans (Hewlett & Cavalli-Sforza, 1986; Guglielmino et al., 1995).

On the other hand, pedagogy is also a type of communication, but unlike any other forms of communication in non-human animals, it conveys generalizable knowledge rather than factual information. All types of communication in non-human animals transmit information about the "here and know", or about particular individuals, that does not generalize to other situations or to other individuals.

Our definition of pedagogy is both wider and narrower than others' use of this or similar terms. Many theorists (e.g., Barnett, 1973; Premack, 1984; Premack & Premack, 1996) see the instructor's feedback and monitoring efforts, which can be called training or 'coaching' (Caro & Hauser, 1992), as integral and essential parts of the teaching process. Although evaluative feedback, as modern educational theories indicate, can obviously facilitate teacher-guided learning, we do not restrict pedagogy to such practices. Our notion of pedagogy is also broader than the notion of *instructed learning* developed by Tomasello, Kruger, & Ratner (1993), which requires the learner to internalize the teacher's instructions and

rehearse them later. We treat any knowledge transmission, as long as it is based on explicit manifestation of knowledge, as evidence for pedagogy, irrespective of whether it involves later rehearsal of internalized instructions or not. On the other hand, we do not consider any behaviour that aims to facilitate the emergence of new knowledge in another individual as pedagogical teaching. Behavioural conditioning by rewards or punishment, or supervised learning in connectionist models, can assist the generation of knowledge, but it does so without explicit communication and knowledge manifestation.

How does pedagogy work then? As we have argued, pedagogy involves a special type of communication, and in order to understand its workings, we have to describe the design specifications of this communication system. Here we shall define the minimum requirements that are necessary for pedagogical knowledge transmission. There are three of them: ostension, reference, and relevance. (We borrowed these terms from the philosophy of language to emphasize the analogy with basic aspects of linguistic communication.)

5.1 Ostension

Pedagogy is costly for the teacher; it requires her to engage in an activity (knowledge manifestation, over and above simple functional knowledge use) that benefits someone else (the learner), but not herself. If she simply *uses* her knowledge, it does not allow others to extract its content from her behaviour – otherwise there would be no need for pedagogy. Therefore the teacher has to make sure that she does not waste her time with manifestations when the intended learner is not in a recipient state. On the other side, the learner has to be able to distinguish whether another individual simply applies her knowledge or demonstrates it for him, because only this latter kind of activity will give him a good chance to extract knowledge from her behaviour. Thus, the teacher has to manifest not only her knowledge to be transmitted to the learner, but also the fact *that* she is manifesting her knowledge, i.e., that she is teaching. This requirement also entails that it is not sufficient if the teacher makes manifest that she is about to teach something; her signals also have to specify the addressee of her teaching attempt (i.e., her intended pupil). In other words, the teacher has to explicitly mark her behaviour as being a pedagogical manifestation, and has to make sure that the intended recipient has received her signals. This requirement is directly analogous, if not identical, to the Gricean view of ostensive communication, which holds that normal human communication makes manifest not juts the intended message content but also the communicative intent of the speaker. We call this aspect of pedagogy, after Sperber & Wilson (1986), *ostension*. From an evolutionary point of view, the strong claim here is that ostensive communication, which, according to several theorists, emerged before linguistic communication during human evolution, originally evolved to assist pedagogy.

The most common way to provide an ostensive stimulus by humans is to talk to each other, but this is not the only way. Making eye contact, for example, is a very powerful communicative signal, and it also specifies the addressee of the concurrent and subsequent message unambiguously. In fact, an ostensive context can entirely be achieved by relatively low-level mechanisms. Teachers and learners can establish a teaching context by emitting and picking up ostensive signals. As these signals are essential for ensuring that the participants mutually recognize that they are in a teaching context, the sensitivity to at least some of these signals must be innate.

5.2 Reference

Pedagogy involves communication of generalizable knowledge that can be used outside the current situation; therefore the teacher also has to specify *what* she is teaching about. Specifying the referent of the to-be-transmitted knowledge content is essential because this will determine for the learner the scope of the acquired knowledge by anchoring the starting point of such generalizations. We shall call this aspect of pedagogy *reference*. Note that our point here is *not* that it is only pedagogy that requires referential communication - many examples of non-human animal communication are also referential (Seyfarth & Cheney, 2003). However, referential messages in animal communication systems (e.g., in monkey alarm calls) are holistic: they do not have to, and they do not, specify the referent separately from the message, because there is no knowledge conveyed by the message that would be generalizable to other referents. The strong evolutionary claim following from this analysis would be that the predicate-argument (knowledge-referent) structure of human communication pre-dates the emergence of language and originates in pedagogical communication.

Reference assignment can take a symbolic, iconic, or indexical format. However, interpreting symbolic reference entails knowledge of symbols, acquired by earlier learning processes, and iconic reference may also require familiarity with the referent. In contrast, indexical referent assignment, especially in terms of spatial indices, can be achieved without prior knowledge about the referent. We assume that the earliest forms of referent assignment in pedagogy, both in phylogenetic and ontogentic timescales, are deictic gestures, like gaze-shift or pointing, and other behaviours that can serve as spatial indices. Note also that while knowledge content is assumed to be

asymmetrical in pedagogical contexts, ostensive and referential signals are not, as they could be produced by either or both participants equally. Thus, setting up the pedagogical context can be initiated by the learner through emitting ostensive signals towards the teacher, and he can also assign reference by deictic gestures for the teacher. If the person to whom these ostensive gestures are addressed interprets these signals as requests for teaching (which is not guaranteed), these ostensive and referential behaviours would function as non-verbal questions to induce transfer of relevant knowledge about the deictically identified referent.

5.3 Relevance

Pedagogy requires the teacher to make manifest the knowledge content to be transmitted to the learner (which is essentially a predicate that holds the referent as (one of) its argument(s)). However, there is no pre-defined code system that could unambiguously represent any new knowledge. Thus, interpretation of manifestations, just like interpretation of observed behaviours, is always *inferential*. Pedagogy solves the inverse problem of action interpretation that we described in section 4 *not* by eliminating inference, but by providing extra information for the learner, which can constrain and channel his inferences towards the appropriate interpretation. There is, however, an important aspect of pedagogy that may help both parties in achieving successful knowledge transfer. Manifesting knowledge content and disambiguating such manifestation can rely on the mutually shared understanding between teacher and learner that what is going on is pedagogical knowledge transfer, i.e., that the teacher's communication conveys *novel and relevant* knowledge to the learner. This aspect of pedagogy, which we call *relevance*, is analogous to the communicative principle of relevance in verbal communication (Sperber & Wilson, 1986) in that it provides guidance for the learner in figuring out the knowledge content that he is supposed to acquire by the teacher's communication.

In order to provide new and relevant knowledge, the teacher has to be able to recognize what knowledge the learner lacks. It is often emphasized that teachers will have to monitor what their pupils understand and adjust their teaching efforts accordingly (e.g., Strauss, Ziv, & Stein, 2002). However, this function can most of the time be fulfilled without actually reading the pupil's mind. If, for example, the teacher, like in a typical parent-offspring setting, can track more or less permanently what knowledge the learner has already acquired, she will be able to identify what would constitute novel knowledge for the learner. It is also important to realize that the teacher does not have to solve the hard inverse problem in order to assess the learner's knowledge state. She does not have to understand what (insufficient or inadequate) knowledge makes the learner behave in a certain way (the inverse problem) — she only has to check if he behaves in accordance with the knowledge that is relevant in the given situation (the forward problem). If he does not, manifesting the relevant knowledge will likely to be beneficial for him.

At the same time, the teacher also has to recognize what it is that she herself knows, and has to be able to analyze this knowledge in terms of its relevance for the learner. This is far from being a trivial achievement. Generally, one does not need to be aware of the content of one's knowledge in order to use that knowledge to generate appropriate behaviour effectively. (This becomes evident when we try to teach a well-practised skill of ours, e.g., how to ride a bike, to someone else. Chicken sex-typers are also famous for typically not being able either to describe or to accessibly demonstrate their amazing skill to others.) Teaching therefore requires a certain amount of *metacognitive* access to one's own knowledge content (Karmiloff-Smith, 1986), to single out and emphasize in her demonstration those aspects of her knowledge that are relevant and novel for the learner, while ignoring others. In other words, a teacher needs to be able to create metarepresentations of her own knowledge (Sperber, 2000). Thus, maybe somewhat paradoxically, this leads us to conclude that while teaching, at least in its initially selected form, does not necessarily require the ability to create metarepresentations of other individuals' representations (i.e., a theory of mind), it does, however, require the ability to develop metarepresentations of one's own knowledge.

On the learner's side, interpreting the teacher's communicative acts in terms of novel knowledge content is not a trivial task either. Such inferences are guided by the assumption that the teacher's acts convey novel and relevant knowledge, but, just like the inferential interpretation of goal-directed acts (Csibra, Bíró, Koós, & Gergely, 2003), they must rely on the learner's already accumulated background knowledge. In fact, the assumption of relevance requires the learner to decode the teacher's manifestation with respect to his *own* knowledge. This implies that while the outcome of the learner's inferential interpretation of the teacher's communicative manifestation will provide him with the teacher's knowledge, the inferential process itself whereby he arrives at this new knowledge content will be based on and constrained by his own, already existing knowledge. In other words, the pedagogical question driving the learner's inferential interpretation of the teacher's demonstration is this: "What is the new information in this manifestation that I don't yet know and would not be able to figure out myself?" To successfully answer this

question it will therefore be necessary for the learner to consult and be guided by the contents of his own existing knowledge. As a result, however, the ensuing output of his inferential interpretation of the teacher's demonstration will enrich his knowledge with the new and relevant information that he was supposed to acquire.

6 Evidence of adaptation for pedagogy in human infants

The design specifications of pedagogy suggest that this adaptation would not be achieved by the emergence of a unitary, single ability that would miraculously solve the problem of knowledge transfer across individuals. Instead, pedagogy works as a well-organized package of biases, tendencies, and skills, many of which are implemented in low-level processes. Considering only the receptive side of pedagogy, such an adaptation should make human infants (1) be sensitive to ostensive stimuli, (2) be biased to follow directional cues in ostensive contexts to identify referents, and (3) be able to extract novel information from manifestations provided by sources in these contexts and learn this information quickly.

6.1 Ostension

An ostensive stimulus is a signal that indicates communication as well as specifies the addressee of the to-be-achieved communication. Human infants are sensitive to at least three kinds of ostensive stimuli from the moment they are born: eye contact, contingent responsivity, and infant-directed speech.

Eye contact is the fastest way to establish and re-establish a communicative link between people. Mutual looking into each other's eyes confirms that the other is "on line", that she is the intended addressee of the other's communicative message. When they can choose, newborns prefer to look at a face directly looking at them, whether that face is a realistic photograph (Farroni, Csibra, Simion, & Johnson, 2002) or a schematic drawing (Farroni et al., 2004). This effect disappears when the faces are presented upside down (Farroni, Johnson, Csibra, & Zulian, unpublished data), which implies that the preferred stimulus for newborns is not simply two eyes with the pupils in their centre, but two eyes with the pupils in their centre in the context of a face that is in a canonical (i.e., upright) position.

Recognizing that an upright face with direct gaze not only signals the presence of a conspecific, but also acts as an ostensive stimulus may provide us with a solution to the puzzle described in section 2.1. If newborns' preference is directed towards ostensive stimuli, they should not be interested in inverted faces, whether or not these involve a direct or an averted gaze, because only faces in the canonical orientation indicate a possible communicative context. In other words, if we interpret the phenomena in question as reflecting 'eye-contact preference' rather than 'face-preference', the puzzle disappears. When looking around in the world, newborns are searching not simply for faces, but for potential 'teachers'. Note that mothers always make sure that their baby's head is aligned with their own when they initiate interactions with their offspring (Watson, 1972).

Another aspect of newborns' preference for faces confirms further that this innate ability is based on more than a geometric face template to be matched. Gaze perception in humans is extremely sensitive to contrast polarity (Ricciardelli, Baylis, & Driver, 2000) because our perceptual system tries to read gaze direction by identifying the location of a darker spot (pupil) within a lighter area (sclera). Human eyes have a unique morphology with large areas of the white sclera visible (Kobayashi & Koshima, 1997). It is possible that this unique morphology serves a human specific function, namely, to make the identification of gaze direction easier for our conspecifics. If 'gaze' is identified by the location of a dark spot on a light background, than a figure that does not have such spots cannot be seen as having a 'gaze' and cannot be identified as a stimulus with mutual gaze (i.e., eye contact). Whether newborns' preference is directed towards stimuli with a specific geometric face configuration, or is determined by the number of elements in the upper and lower parts of the stimuli (Turati, Simion, Milian, & Umiltà, 2002; Cassia, Turati, & Simion, 2004), they should show preference for upright face configurations even if the contrast polarity of these stimuli are inverted. If, however, their preference is directed to potential eye contact stimuli, where eyes are defined as dark spots on light background in the context of a canonically oriented face, they should not show any preference, because neither of those stimuli satisfies this definition. A recent study (Farroni, Johnson, & Csibra, unpublished data) confirmed this latter prediction.

Another ostensive stimulus is contingency. If a source repeatedly appears to remain silent during your actions but start to emit signals as soon as you have stopped your actions, it gives you the strong impression that the source is communicating with you. In fact, this kind of turn-taking temporal contingency is a characteristic feature of normal human communication. Newborns are known to be sensitive to such temporal contingency, as it is shown by the fact that they can be subjected to operant conditioning (e.g., Floccia, Christophe, & Bertoncini, 1997). Although their behavioural repertoire is very limited, they nevertheless use those of their actions that they can control voluntarily relatively well, like sucking, to test if

they receive contingent responses from their mother (Masataka, 2003).

Contingent turn taking remains a very important factor in mother-infant communication during the first months of life. These types of early interactions received a lot of attention, and were hailed as providing evidence for the innate sociability of human infants. These contingent interactions are sometimes called 'proto-conversation' (Bateson, 1979), 'dyadic interaction' (Stern, 1977) or 'primary intersubjectivity' (Trevarthen, 1979), and it has been attributed various functions, like 'sharing mental states' (Trevarthen, 1979), 'affect attunement' (Stern, 1977), 'mutual affect regulation' (Gianino & Tronick, 1988), or serving identification (Tomasello, 1999) or attachment purposes (e.g., Watson, 2001). While we agree that some of these processes may indeed be assisted by early conversation-like interactions, we do not believe that the primary function of human infants' innate sensitivity to contingent turn taking is the fulfilment of any of these functions (see Gergely, 2002). For example, filial attachment is established in many mammalian and avian species without extended proto-conversational routines. It also seems to be an overstatement that mothers and infants are both motivated to and subjectively aware of 'sharing' each other's mental or emotional states in these interactions. No doubt, they both enjoy these situations, and one can say that they, in fact, 'share' this positive hedonic experience at least in the sense of being simultaneously in a similar affective state. Also, apart from generating simultaneous enjoyment, what aspect of the evidence would indicate that any other, more differentiated discrete emotional states are shared during turn taking? Do mothers and babies share sadness, fear, anger, disgust, or distress? Infants may be able to recognize the expressions of these emotional states, and mothers will certainly react to these emotions if their child expresses them. But this reaction will hardly be an initiation of a turn taking interchange: she is much more likely to just pick the child up and establish close bodily contact with him. Engaging in proto-conversational turn taking is neither a typical nor an effective response when the baby is in need of soothing.

The fact that young infants enjoy contingent interactions even in the absence of another human being (for example, with a mobile, see Watson, 1972) also suggests that the sensitivity to contingent responsivity does not imply a sharing of emotional states or identification with the source of contingency. We believe that these early dyadic interactions serve an ultimately epistemic function: identifying teachers and teaching situations, and practising this process. It is adaptive to seek out such situations because they indicate the potential to acquire a commodity that has survival value: socially transmitted and culturally relevant knowledge.

Perhaps the most obvious communicative signal in humans is the most used form of communication itself: speech. Unlike the other two communication signals, however, speech itself is not necessarily an ostensive stimulus, as it does not directly specify the addressee of a communicative act. To figure out if one is being addressed by a speech signal, one can look for the presence of other ostensive stimuli, like eye contact or contingency, or can try to disambiguate the situation from the content of the speech. This latter method of disambiguation, however, is not available to preverbal infants. Nevertheless, speakers can provide additional cues in the auditory domain to indicate that they are talking to an infant. Adults, and especially mothers, instinctively alter their prosody when they talk to preverbal infants. The prosody of infant-directed speech, often termed as 'motherese', is characterized by higher pitch, broader pitch and amplitude variation, and lower speed than adult-directed speech.

Several functions have been attributed to this distinctive type of speech pattern addressed to infants: it captures infants' attention (Fernald, 1985), it regulates affects (Werker & McLeod, 1989), it may play a causal role in language acquisition (Furrow, Nelson, & Benedict, 1980), or it is just a by-product of the fact that infants are talked to in emotionally charged contexts (Trainor, Austin, & Desjardins, 2000; Singh, Morgan, & Best, 2002). We propose that the primary function of motherese is much simpler: it merely *makes it manifest that the speech is infant-directed*. In other words, the special prosody associated with motherese indicates to the baby that he is the one to whom the given utterance is addressed. This signalling function turns motherese into the sibling of eye contact and contingent responsivity, as it will also indicate to the child that he is in a potential pedagogical context. If this is the case, we should see that infant-directed speech elicits the same responses as do the other two cues: easy and fast detection of, preferential orientation to, and positive affect towards the source of such stimuli.

Indeed, two-day-old newborns pay more attention to a source talking to them in infant-directed speech than to a source speaking in an adult-directed way (Cooper & Aslin, 1990), even if they are born to congenitally deaf parents who could not have trained them in special speech patterns prenatally (Masataka, 2003). Older infants prefer motherese even if the speech represents a foreign language never heard before (Werker, Pegg, & McLeod, 1994), and are more likely to extract motherese than adult-directed speech from acoustic noise (Colombo et al., 1995). Infants' responses to motherese, just like their responses to eye contact and contingency, also have an affective

component. When they attend to infant-directed speech, babies smile more and appear to be more attractive to adults than when they are listening to adult-direct speech (Werker & McLeod, 1989). This shows that infants' response to motherese, just like their response to eye contact, fulfils its function: it makes adults repeat their actions and prolong the (potentially pedagogical) interaction with them.

Finally, we have to mention that the earliest word that infants recognize at 4.5 months of age is an ostensive stimulus: their own name (Mandel, Jusczyk, & Pisoni, 1996). Of course, sensitivity to their own name is not inborn, but it is also unlikely that their name at this age would function as a lexical item referring to the self. Instead, this word must have acquired a special status via strong associations with other ostensive stimuli, like eye contact or motherese, and its "meaning" for an infant is entirely defined by pragmatic rather than semantic factors. From about 6 months, infants spontaneously turn their head when their name is called, showing that they interpret this word as a vocative.

6.2 Reference

The widespread view among students of infant communication is that referential communication does not exist before the second half of the first year of life. Young infants are restricted to affective communication, and only some time after 6 months of age can they change over from dyadic to triadic interactions, from primary to secondary intersubjectivity, and from affective to referential communication (e.g., Adamson & McArthur, 1995; Butterworth, 2004; Masataka, 2003; Tomasello, 1999; Trevarthen & Aitken, 2001). This developmental stage is characterized by the emergence of episodes of 'joint attention', where the infant and another person (usually a caregiver) simultaneously attend to the same object, while they are mutually aware that they share their experience. Joint attention can be initiated by either party, especially after the infant has started to point to objects at the end of the first year.

While we agree that infants' receptive and productive communicative abilities extend enormously during the first year, we think that this two-stage-view of early communication has to be revised in the light of recent results. In particular, several studies have shown that young infants are sensitive to gaze shifts in faces that they observe. If 4-month-old infants see that the gaze direction of a person suddenly shifts to one side, they will be more likely, and faster, to detect and localize a target stimulus on the same side than on the other side (Farroni, Johnson, Brockbank, & Simion, 2000; Hood, Willen, & Driver, 1998). They do not necessarily follow the gaze (while sometimes they do; gaze-following cannot be reliably triggered by eye-movement alone until 18 months of age), but their attention is sensitized to events in the indicated direction. In fact, the same effect of gaze-triggered attentional shift is also present in newborns (Farroni et al., 2004). If the adult turns her head as well, and the target objects are close enough, overt gaze following can also be elicited in young infants (D'Entremont, Hains, & Muir, 1997).

These phenomena are usually interpreted as reflecting infants' sensitivity to the attentional state of others. There is an important aspect of these results, however, that calls this interpretation into question. Infants shift their attention to the direction of the gaze of the observed person only if (1) they can see the eyes moving to the side position (Farroni et al., 2000), and (2) the eyes are departing from central, i.e., eye-contact, position (Farroni, Mansfield, Lai, & Johnson, 2003). If what infants are interested in is the direction of attention of the other person, they should not care about where she was looking before; her attention, or her shift of attention, could be read out from her final eye position in any case. This pattern of results, however, is consistent with an alternative interpretation, which claims that infants follow others' gaze, or are at least sensitized to the visual field of the direction of gaze shifts of others, because they conceive gaze shifts as referential acts (Csibra, 2003). Directional stimuli from another person will only be interpreted as referential actions if they occur in an ostensive situation, established, for example, by eye contact. In fact, if the communicative situation has been established by eye contact, infants seem to be sensitized by any motion coming from the ostensive stimulus, even if it is not a gaze shift (Farroni et al., 2000). Further, 'gaze following' could also be elicited without a face, if the ostensive stimulus is provided by contingency, rather than eye contact, information (Johnson, Slaughter, & Carey, 1998; Movellan & Watson, 2002).

The fact that young infants tend to interpret the actions of the source of an ostensive stimulus as referential does not guarantee that they will also be able to identify the referent. Studies have shown that the accuracy of finding the target object of a referential act, whether it is looking or pointing, is developing slowly during the first 18 months (Butterworth & Jarrett, 1991), especially if the referent is in a distal position or it is outside of the baby's visual field (Flom, Deák, Phill, & Pick, 2004). If the function of gaze following were to allow the infant to 'share' the attentional state of another person (e.g., Tomasello, 1999), this inaccuracy would be puzzling (see section 2.2). Why would such a response survive if it failed to achieve successful 'sharing' and would lead to a misinterpretation of what the object of the other's mental experience is most of the time? If, however, gaze following reflects a communicative-referential

expectation, this is not a problem: An infant can confidently expect that his communicative partner (the 'teacher') would specify the referent in a way that he could decode it, or that she would repeat and extend the referential cues if the baby has not succeeded in locating it. And if he still failed to find the referent, he would only run into the risk of missing an opportunity to learn something from his teacher rather than mis-attributing a mental state to her.

It is also important that infants expect that a referential action would specify something that they can learn about, for example, an object. When infants make a mistake in studies on gaze following, their gaze never stops at an empty surface, but always lands on an object (Butterworth & Jarrett, 1991). Similarly, if reference is specified by jiggling and moving an object in front of the infant after making eye contact with him, a 3- or 4-month-old baby's gaze will stick to the object even after the hand has been withdrawn from it (Amano, Kezuka, & Yamamoto, 2004). And when they can identify the referred location but not the referent because it is behind a barrier, they will locomote to get a view of the referred object (Moll & Tomasello, 2004). Infants therefore have a strong expectation that the actions of a person (or, in fact, any source) that emits ostensive stimuli towards them will highlight an object (or event), which they are supposed to attend to. While it is true that this tendency will most of the time establish 'joint attention' between the infant and the source, we believe that the function of this outcome is neither to uncover others' mental states for the infants, nor to share experience between them, but to specify for the infant what it is that he is going to be taught about some new and relevant information. Infants are prepared from birth to interpret actions as referential. The impression of stage-like development of communication is simply created by the fact that while ostensive stimuli are innately specified (and elicit strong affective responses), the mechanisms of indexical referent identification are only crudely defined at birth, and have to be tuned by slow perceptual learning during early development.

6.3 Relevance

The function of pedagogy is to allow transfer of culturally accumulated knowledge to new members of the community. The actual content of this knowledge can fall into various domains: function and use of tools, valence of objects or animals, some aspects of language (primarily words), non-linguistic symbols (for example, gestures), cultural conventions, and even abstract beliefs expressing the world view of the community. Learning in all these domains can rely on some specialized cognitive mechanisms, and never depends exclusively on explicit teaching. Nevertheless, teaching would accelerate learning by warranting the relevance of the acquired knowledge. This is achieved if the learner assumes that the teacher's communication will increase his knowledge by novel elements. Infants and children indeed apply this assumption when they are subject to teaching and this can be demonstrated in all the domains we listed above. Here we illustrate the functioning of this assumption in the domain of tool use.

If one assumes that a certain unfamiliar object has a function to serve, he can try to figure out what it is without assistance. He can take the 'design stance' (Dennett, 1987) and look for the intended use of the artefact. Young children and infants are unlikely to be able to go down this route (Matan & Carey, 2001), but that does not imply that they would not be able to understand and reason about functions (Kemler Nelson, Egan, & Holt, 2004) or that they would be helpless in finding out what an artefact is for. They could, for example, try out various actions with it to find out the object's affordances. Human infants (unlike infants of most other animals) are indeed fascinated by objects and enjoy manipulating them. Trial-and-error methods, however, as we discussed in section 4, can only have a limited use in discovering artefact functions. We hypothesized that pedagogy might have originally developed to transmit knowledge about non-obvious artefact functions and usage. When a learner is taught how to use a tool, he does not have to understand either the ultimate function of the object or the rationale that justifies a particular procedure applied to the tool. In accordance with this purpose, and perhaps counter-intuitively at first sight, the relevance assumption will dictate to the learner to attend to those aspects of a demonstrated tool use that he would not be able to infer from his existing knowledge (i.e., those aspects that do not make sense for him), and conclude that he has been taught these novel aspects.

In a well-known study on infant imitation, Meltzoff (1988) demonstrated a novel action on a novel object to 14-month-old infants. The model made eye contact with the infant and then conspicuously leaned forward and touched a box with her forehead, lighting it up. One week later, when they came back to the laboratory and had a chance to approach the object, the majority of the infants replicated the action that they had seen performed only once before. This is a textbook example of pedagogical learning: the teacher (the model) (1) established a teaching context by an ostensive stimulus (eye contact), (2) identified the referent object (the magic box) by looking at it and touching it, and (3) demonstrated a novel action (touching the box with her forehead) that created a novel effect (lighting up the box). In response, infants learned in a single trial both the function of the novel object and the special way it should be

operated, and retained this knowledge for a relatively long time. The answer to the question raised in section 2.3, "Why do infants imitate a novel action even when they have access to a more efficient means to achieve the same end?" is simply, "Because they have been taught to perform that action."

This interpretation of Meltzoff's study is markedly different from what he and others (e.g., Tomasello, 1999) offered. Meltzoff (and Tomasello) reasoned that infants imitated the model's unusual action because they identified with her, and this made them copy her action when they had the same goal as the model had had before. Thus, according to this interpretation, infants' imitative behaviour does not depend on either the teaching context or the novelty aspect of the demonstration. Recent studies tested some differential predictions of these contradicting interpretations. Gergely, Bekkering, & Király (2002) modified Meltzoff's situation in a way that rendered the same action understandable, hence removing its relevance. Before demonstrating the head-touch action, the model – pretending to be chilly – covered her shoulders with a blanket that she had to hold on to by her hands to keep it on. In this situation, where the hands are no longer available, the head-touch action seems to be the most efficient way to touch an object in front of the model. By 14 months of age infants are known to understand that agents normally act efficiently to achieve their goals (Csibra et al., 1999; Gergely, Nádasdy, Csibra, & Bíró, 1995); therefore the model's action in this situation did not represent any novel information for them. If infants conceived the situation as a teaching attempt, they would learn the function of the novel object, but they would not learn the particular action the object was operated by because it did not represent new and relevant knowledge. This prediction was confirmed when the infants returned to the laboratory a week later; hardly any of them imitated the head-touch action in this 'hands-occupied' demonstration condition, while all of them operated the box using their hand.

The pedagogical account of Meltzoff's study also suggests that the ostensive stimuli before the demonstration might have played a critical role in defining the context as teaching. Király, Csibra, & Gergely (2004) replicated Meltzoff's study with the single modification that the model never made any eye contact with the infants, who therefore observed the same actions outside of a teaching context. Despite the fact that these infants saw exactly the same demonstration, only a minority of them imitated the novel action. Imitation is a ubiquitous phenomenon in human social learning (whether or not it is exclusive to humans); however, it is not an end but a means. It subserves a more general human-specific adaptation of acquiring relevant knowledge from teachers who are willing to manifest such knowledge (for a more thorough discussion of the role of imitation in human development see Gergely & Csibra, in press).

7 Pedagogy and social cognition

Just like the general learning mechanisms that implement individual knowledge acquisition, the design of pedagogical knowledge acquisition also relies on implicit assumptions about the world. Associationist learning, for example, assumes stable or permanent relations between the associated events, and food avoidance learning assumes a causal link between the consumption of a new food item and the subsequent sickness. In case these assumptions were false, the learning mechanisms would not yield valid and adaptive knowledge. Similarly, pedagogical learning makes assumptions about the social world without which the adaptivity of such a knowledge acquisition system would collapse. These assumptions determine fundamentally the picture that we create about our conspecifics, and they form the core of our social cognitive development.

The first assumption that an infant must hold in order to take advantage of pedagogy is that there will be 'teachers' around who will transmit relevant knowledge to him. Teaching is a cooperative activity that incurs no immediate benefit for the teacher while it may be costly for her (cf. Caro & Hauser, 1992). Note also that the advantages of pedagogical knowledge transfer over other types of observational social learning (i.e., rapid acquisition, unrestricted content) arise only if the learner trusts the teacher unconditionally, without verifying the relevance of the acquired knowledge. This *cooperativity* assumption seems to apply not only to family members, since infants are happy to learn new skills from experimenters in hundreds of developmental psychology laboratories around the world. As this is a core assumption, it is applied "by default" to everyone in every situation, and (probably in contrast to other animals) what human children have to learn by experience is when to suspend this assumption.

The second general assumption of pedagogical knowledge acquisition is that mature members of the community store valuable knowledge in themselves that they can manifest any time, even when they are not in need to use the knowledge themselves. Note that this assumption is not equivalent to rendering other people's minds as representational devices because the existence and validity of their knowledge is presumed. Indeed, this assumption implies that infants will see other people (or at least adults) as *omniscient*, whose knowledge is available to tap at any time (for an opposite view, see Baldwin & Moses, 1996). Thus, what children have to learn by experience is not the

conditions that make people knowledgeable but the conditions that make people ignorant.

Finally, a corollary of the omniscience assumption is that the knowledge that the child acquires is public, shared, and universal. If someone knows something, everyone knows it; otherwise the assumption of omniscience would be violated. This assumption is analogous to the similar assumption about words: a child can plausibly assume that a word learned from a certain person is not her specific way to express a certain concept, but part of a shared sign system. The assumption of *universality* implies that whatever the child knows (especially if it was taught to him) will be known by everyone. Though this will be a valid inference most of the time, children eventually have to learn the conditions under which this assumption should be suspended to overcome the erroneous conclusions that have recently been dubbed as the 'curse of knowledge' (Birch & Bloom, 2004).

If our hypothesis about the fundamental role that pedagogy has played during human evolution and plays during human development is correct, this would then also imply that seeing each other as cooperative and omniscient individuals is also part of our nature. And though one aspect of social cognitive development will necessarily be to learn when to overcome (suspend or inhibit) these default assumptions, we would never get rid of them. We expect that many people will resist the idea that important aspects of human social cognition and cooperation are derived from an originally epistemic function (i.e., knowledge acquisition). In our view, however, discovering that the evolutionary design of a basic human adaptation, such as pedagogy, involves built-in assumptions about the social world would not degrade but rather strengthen our understanding and appreciation for the inherent sociability of humans.

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References

Adamson, L. & McArthur, D. (1995). Joint attention, affect, and culture. In: C. Moore & P. J. Dunham (Eds.), *Joint Attention: Its Origins and Role in Development* (pp. 205-221). Hillsdale: Lawrence Erlbaum.

Amano, S., Kezuka, E., & Yamamoto, A. (2004). Infant shifting attention from an adult's face to an adult's hand: a precursor of joint attention. *Infant Behavior and Development, 27*, 64-80.

Baldwin, D. A. & Moses, L. J. (1996). The ontogeny of social information gathering. *Child Development, 67*, 1915-1939.

Barnett, S. A. (1973). Homo docens. *Journal of Biosocial Science, 5*, 393-403.

Bateson, M. C. (1979). 'The epigenesis of conversational interaction': a personal account of research development. In: M. Bullowa (Ed.), *Before Speech: The Beginning of Interpersonal Communication* (pp. 63-77). New York: Cambridge University Press.

Birch, A. J. & Bloom, P. (2004). Understanding children's and adults' limitations in mental state reasoning. *Trends in Cognitive Sciences, 8*, 255-260.

Butterworth, G. (2004). Joint visual attention in infancy. In: G. Bremner & A. Slater (Eds.), *Theories of Infant Development* (pp. 317-354). Oxford: Blackwell.

Butterworth, G., & Jarrett, N. (1991). What minds have in common is space: Spatial mechanisms serving joint visual attention in infancy. *British Journal of Developmental Psychology, 9*, 55-72.

Caro, T. M. & Hauser, M. D. (1992). Is there teaching in nonhuman animals? *The Quarterly Journal of Biology, 67*, 151-174.

Cassia, V. M., Turati, C., & Simion, F. (2004). Can a nonspecific bias toward top-heavy patterns explain newborns' face preference? *Psychological Science, 15*, 379-383.

Colombo, J., Frick, J. E., Ryther, J. S., Coldren, J. T., & Mitchell, D. W. (1995). Infants' detection of analogs of "motherese: in noise. *Merrill-Palmer Quarterly, 41*, 104-113.

Cooper, R. P. & Aslin, R. N. (1990). Preference for infant-directed speech in the first month after birth. *Child Development, 61*, 1584-1595.

Csibra, G. (2003). Teleological and referential understanding of action in infancy. *Philosophical Transactions of the Royal Society, London, B, 358*, 447-458.

Csibra, G**.**, Bíró, S., Koós, S., & Gergely, G. (2003). One-year-old infants use teleological representations of actions productively. *Cognitive Science, 27*, 111-133.

Csibra, G., Gergely, G., Bíró, S., Koós, O., & Brockbank, M. (1999). Goal attribution without agency cues: The perception of 'pure reason' in infancy. *Cognition, 72*, 237-267.

D'Entremont, B., Hains, S. M. J., & Muir, D. W. (1997). A demonstration of gaze following in 3- to 6-month-olds. *Infant Behavior and Development, 20*, 569-572.

Dennett, D. (1995). *Darwin's Dangerous Idea: Evolution and the Meanings of Life*. New York: Simon and Schuster.

Dennett, D. (1987). *The Intentional Stance*. Cambridge: MIT Press.

Dunbar, R. (1996). *Grooming, Gossip and the Evolution of Language*. London: Faber and Faber.

Farroni, T., Csibra, G., Simion, F., & Johnson, M. H. (2002). Eye contact detection in humans from birth. *Proceedings of the National Academy of Sciences of the United States of America, 99*, 9602-9605.

Farroni, T., Johnson, M. H., Brockbank, M., & Simion, F. (2000). Infants' use of gaze direction to cue attention: The importance of perceived motion. Visual-*Cognition, 7*, 705-718.

Farroni, T., Mansfield, E. M., Lai, C., & Johnson, M. H. (2003). Infants perceiving and acting on the eyes: tests of an evolutionary hypothesis. *Journal of Experimental Child Psychology, 85*, 199-212.

Farroni, T., Massaccesi, S., Pividori, D., Simion, F., &

Johnson, M. H. (2004). Gaze following in newborns. *Infancy, 5*, 39-60.

Fernald, A. (1985). Four-month-old infants prefer to listen to motherese. *Infant Behavior and Development, 8*, 181-195.

Floccia, C., Christophe, A., & Bertoncini, J. (1997). High-amplitude sucking and newborns: The quest for underlying mechanisms. *Journal of Experimental Child Psychology, 64*, 175-189.

Flom, R., Deák, G. O., Phill, C. G., & Pick, A. D. (2004). Nine-month-olds shared visual attention as a function of gesture and object location. *Infant Behavior and Development, 27*, 181-194.

Furrow, D., Nelson, K., & Benedict, H. (1980). Mothers' speech to children and syntactic development: Some simple relationships. *Journal of Child Language, 6*, 423-442.

Gergely, G (2002). The development of understanding self and agency. In U. Goshwami (Ed.), *Blackwell Handbook of Childhood Cognitive Development*, (pp. 26-46). Oxford: Blackwell.

Gergely, G., Bekkering, H., & Király, I. (2002). Rational imitation in preverbal infants. *Nature, 415*, 755.

Gergely, G. & Csibra, G. (in press). Sylvia's recipe: Human culture, imitation, and pedagogy. In: N. J. Enfield & S. C. Levinson (Eds.), *Roots of Human Sociality: Culture, Cognition, and Human Interaction*. Berg Press, London.

Gergely, G., Nádasdy, Z., Csibra, G., & Bíró, S. (1995). Taking the intentional stance at 12 months of age. *Cognition, 56*, 165-193.

Gianino, A. & Tronick, E. Z. (1988). The mutual regulation model: The infant's self and interactive regulation and coping and defensive capacities. In: T. M. Field, P. M. McCabe, & N. Schneiderman (Eds.), *Stress and Coping Across Development* (pp. 47-68). Hillsdale: Lawrence Erlbaum.

Guglielmino, C. R., Viganotti, C., Hewlett, B., & Cavalli-Sforza, L. L. (1995). Cultural variation in Africa: Role of mechanisms of transmission and adaptation. *Proceedings of the National Academy of Sciences of the United States of America, 92*, 7585-7589.

Hewlett, B. S. & Cavalli-Sforza, L. L. (1986). Cultural transmission among Aka pygmies. *American Anthropologist, 88*, 922-934.

Hood, B. M., Willen, J. D., & Driver, J. (1998). Adult's eyes trigger shifts of visual attention in infants. *Psychological Science, 9*, 131-134.

Johnson, M. H. & Morton, J. (1991). *Biology and Cognitive Development: The Case of Face Recognition*. Oxford: Blackwell.

Johnson, S. C., Slaughter, V., & Carey, S. (1998). Whose gaze will infants follow? The elicitation of gaze-following in 12-month-olds. *Developmental Science, 1*, 233-238.

Karmiloff-Smith, A. (1986). From meta-processes to conscious access: Evidence from children's metalinguistic and repair data. *Cognition, 23*, 95-147.

Kemler Nelson, D. G., Egan, L. C., & Holt, M. B. (2004). When children ask, "What is it" what do they want to know about artifacts? *Psychological Science, 15*, 384-389.

Király, I., Csibra, G., & Gergely, G. (2004). The role of communicative-referential cues in observational learning during the second year. Poster presented at the 14th Biennial International Conference on Infant Studies, May 2004, Chicago, IL, USA.

Kobayashi, H., & Kohshima, S. (1997). Unique morphology of the human eye. *Nature, 387*, 767-768.

Kruger, A. & Tomasello, M. (1996). Cultural learning and learning culture. In D. Olson & N. Torrance (Eds.), *The Handbook of Education and Human Development* (pp. 369-387). Oxford: Blackwell.

Laland, K. N., Odling-Smee, J., & Feldman, M. W. (1999). Niche construction, biological evolution, and cultural change. *Behavioral and Brain Sciences, 23*, 146-175.

Mandel, D. R., Jusczyk, P. W., & Pisoni, D. B. (1995). Infants' recognition of the sound patterns of their own names. *Psychological Science, 6*, 314-317.

Masataka, N. (2003). *The Onset of Language*. New York: Cambridge University Press.

Matan, A. & Carey, S. (2001). Developmental changes within the core of artifact concepts. *Cognition, 78*, 1-26.

Meltzoff, A. N. (1988). Infant imitation after a 1-week delay: Long-term memory for novel acts and multiple stimuli. *Developmental Psychology, 24*, 470-476.

Moll, H. & Tomasello, M. (2004). 12- and 18-month-old infants follow gaze to spaces behind barriers. *Developmental Science, 7*, F1-F9.

Moore, C. & Dunham, P. J. (1995). *Joint Attention. Its Origins and Role in Development*. Hillsdale, NJ: Lawrence Erlbaum.

Movellan, J. R. & Watson, J. S. (2002). The development of gaze following as a Bayesian systems identification problem. UCSD Machine Perception Laboratory Technical Reports 2002.01.

Olson, D. R. & Bruner, J. S. (1996). Folk psychology and folk pedagogy. In D. R. Olson & N. Torrance (Eds.), *The Handbook of Education and Human Development* (pp. 9-27). Oxford: Blackwell.

Premack, D. (1984). Pedagogy and aesthetics as sources of culture. In M. S. Gazzaniga (Ed.), *Handbook of Cognitive Neuroscience* (pp. 15-35). New York: Plenum Press.

Premack, D. & Premack, A. J. (1996). Why animals lack pedagogy and some cultures have more of it than others. In D. R. Olson & N. Torrance (Eds.), *The Handbook of Education and Human Development* (pp. 302-323). Oxford: Blackwell.

Premack, D. & Premack, A. (2003). *Original Intelligence. Unlocking the Mystery of Who We Are*. New York: McGraw-Hill.

Ricciardelly, P., Baylis, G., & Driver, J. (2000). The positive and negative of human expertise in gaze perception. *Cognition, 77*, B1-B14.

Seyfarth, R. M. & Cheney, D. L. (2003). Signalers and receivers in animal communication. *Annual Review of Psychology, 54*, 145-173.

Singh, L., Morgan, J. L., & Best, C. T. (2002). Infants' listening preferences: Baby talk or happy talk? *Infancy, 3*, 365-394.

Sperber, D. (2000). Metarepresentations in an evolutionary perspective. In: D. Sperber (Ed.), *Metarepresentations: A Multidisciplinary Perspective* (pp. 117-137). Oxford: Oxford University Press.

Sperber, D. & Wilson, D. (1986). *Relevance: Communication and Cognition*. Oxford: Blackwell.

Stern, D. (1977). *The First Relationship: Infant and Mother*. London: Fontana Books.

Strauss, S., Ziv, M., & Stein, A. (2002). Teaching as a natural cognition and its relations to preschoolers' developing theory of mind. *Cognitive Development, 17*, 1473-1787.

Tomasello, M. (1996). Do apes ape? In: C. M. Heyes & B. G. Galef, (Eds.). *Social Learning in Animals: The Roots of Culture*. NY: Academic Press.

Tomasello, M. (1999). *The Cultural Origins of Human Cognition*. Cambridge, MA: Harvard University Press.

Tomasello, M., Kruger, A., & Ratner, H. (1993). Cultural learning. *Behavioral and Brain Sciences, 16*, 495-511.

Trainor, L. J., Austin, C. M., & Desjardins, R. N. (2000). Is infant-directed speech prosody a result of vocal expression of emotion? *Psychological Science, 11*, 188-195.

Trevarthen, C. (1979). Communication and cooperation in early infancy: a description of primary intersubjectivity. In: M. Bullowa (Ed.), *Before Speech: The Beginning of Interpersonal Communication* (pp. 321-347). New York: Cambridge University Press.

Trevarthen, C. & Aitken, K. J. (2001). Infant intersubjectivity: research, theory, and clinical applications. *Journal of Child Psychology and Psychiatry, 42*, 3-48.

Turati, C., Simion, F., Milini, I., & Umiltà, C. (2002). Newborns' preference for faces: What is crucial? *Developmental Psychology, 38*, 875-882.

Valenza, E., Simion, F., Cassia, V. M., & Umiltà, C. (1996). Face preference at birth. *Journal of Experimental Psychology: Human Perception and Performance, 22*, 892-903.

Want, S. C., & Harris, P.L. (2002). How do children ape? Applying concepts from the study of non-human primates to the developmental study of 'imitation' in children. *Developmental Science, 5,* 1-41.

Watson, J. S. (1972). Smiling, cooing, and “the game”. *Merrill-Palmer Quarterly, 18*, 323-339.

Watson, J. S. (2001). Contingency perception ad misperception in infancy: Some potential implications for attachment. *Bulletin of the Menninger Clinic, 65*, 296-320.

Werker, J. F. & McLeod, P. J. (1989). Infant preference for both male and female infant-directed talk: a developmental study of attentional and affective responsiveness. *Canadian Journal of Psychology, 43*, 320-346.

Werker, J. F., Pegg, J. E., & McLeod, P. J. (1994). A cross-language investigation of infant preference for infant-directed communication. *Infant Behavior and Development, 17*, 323-333.

Whiten, A. (1999). Parental encouragement in *Gorilla* in comparative perspective: implications for social cognition and the evolution of teaching. In S. T. Parker, R. W. Mitchell, & H. L. Miles (Eds.), *The Mentalities of Gorillas and Orangutans in Comparative Perspective* (pp. 342-466). Cambridge University Press.

Whiten, A. (2000). Primate culture and social learning. *Cognitive Science, 24*, 477-508.

Wood, D., Bruner, J., & Ross, G. (1976). The role of tutoring in problem solving. *Journal of Child Psychology and Psychiatry, 17*, 89-100.

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