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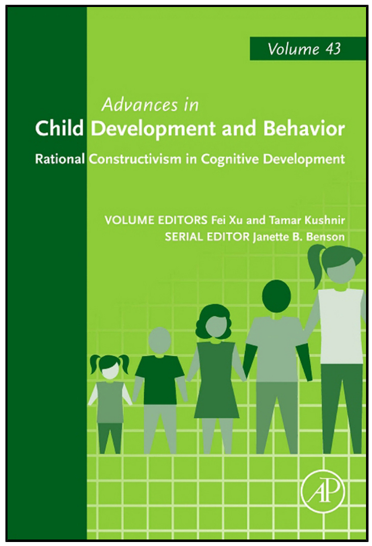

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CHAPTER THREE

Reasoning about Instrumental and Communicative Agency in Human Infancy

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Abstract

Theoretical rationality and practical rationality are, respectively, properties of an individual's belief system and decision system. While reasoning about instrumental actions complies with practical rationality, understanding communicative actions complies with the principle of relevance. Section 2 reviews the evidence showing that young infants can reason about an agent's instrumental action by representing her subjective motivations and the episodic contents of her epistemic states (including false beliefs). Section 3 reviews the evidence showing special sensitivity in young human infants to some ostensive behavioral signals encoding an agent's communicative intention. We also address the puzzle of imitative learning of novel means actions by 1-year olds and argue that it can be resolved only by assuming that the infant construes the model's

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demonstration as a communicative, not an instrumental, action. Section 4 reviews the evidence for natural pedagogy, a species-unique social communicative learning mechanism that exploits human infants' receptivity to ostensive–communicative signals and enables infants to acquire kind-wide generalizations from the nonverbal demonstrations of communicative agents. We argue that the essentialist bias that has been shown to be involved in children's concepts of natural kinds also applies to infants' concepts of artifacts. We further examine how natural pedagogy may also boost inductive learning in human infancy.

1. INTRODUCTION: THE MANY FACES OF HUMAN REASON

Philosophers draw a basic distinction between practical and theoretical rationality. While practical rationality is a property of an agent's decision system, theoretical rationality is a property of an agent's belief system. An agent's decision is rational if it selects an action that is likely to maximize the agent's utility function (i.e. the agent's desire or preference about, e.g., commodities) in light of her beliefs (about, e.g., the prices of commodities). A belief is deemed rational if its content stands in deductive and/or inductive relations to the contents of other accepted beliefs, which warrant its acceptance (cf. Davidson, 1980, 2004 and Dennett, 1978, 1987).

The human ability to entertain *reasons for believing*, however, is not restricted to theoretical rationality so defined. Humans evolved species-specific ways to acquire beliefs based on *communication* (Recanati, 2001; Sperber, 1997). As a result, they are unique in their evolved capacity to create, transmit, maintain, and stabilize across generations an increasing body of cultural beliefs ranging over technology, social traditions, history, religion, the law, the arts, science, and mathematics. To simplify, humans can accept a culturally transmitted belief for one of two reasons (or both): its *content* or the *authority* of its source (Sperber, 1997, 2001, Sperber et al., 2010).

To accept a culturally transmitted belief on account of its content is to grasp its deductive relations to the contents of other beliefs and/or its inductive relations to the evidence, in accordance with the principles of theoretical rationality. A culturally transmitted belief can also be accepted on account of the authority of its source. We shall call *deferential* such culturally transmitted beliefs (Recanati, 1997). A deferential belief can be accepted either because its source is known, remembered, and judged to be reliable (or trustworthy) or because it is taken to be shared common knowledge among members of one's community. When accepted by deference to the authority of its source, the content of a culturally transmitted belief may to a large extent remain cognitively *opaque* to the individual who subscribes to it. In some cases, further cognitive processing may make the opaque content of a deferentially acquired belief more transparent by tracking its inferential connections to the contents of other beliefs and to later acquired relevant evidence. In human adult social life, deferential beliefs are ubiquitous, and so are beliefs whose contents may remain cognitively opaque to the individuals who accept them throughout their lives.

Since it is based on trust (i.e. judgments about the authority of their source), the acceptance of deferential beliefs is not entirely groundless or unjustified. To accept a deferential belief is to fulfill the informative intention of an agent who performed a communicative action in accordance with the principle of *relevance* (cf. Sperber & Wilson, 1995, 2012; Wilson & Sperber, 2002). On the approach by Sperber & Wilson (1995), a piece of communicated information is said to be more relevant than a competing one if by attending to the former the addressee of the communicative act can derive more cognitive benefit than by attending to the latter. The cognitive benefit of a relevant piece of information is in turn conceptualized in terms of a trade-off between the cognitive effects produced by the novel implications arrived at and the cognitive effort devoted to processing these implications.

From birth on, human infants are exposed to two basic kinds of intentional agency: *instrumental* and *communicative* agency (Gergely, 2010). While they observe agents perform instrumental actions as a means to satisfy their subjective desires and preferences, infants are also the recipients of the actions of agents with communicative intentions whose fulfillment depends on their being recognized by their addressees. Making sense of an agent's noncommunicative instrumental action requires the third-personal ascription to the agent of a goal or intention to achieve some desirable outcome in light of her beliefs about the world, in accordance with the principle of practical rationality (Dennett, 1987; Fodor, 1992). By contrast, when being addressed by an agent's ostensive–communicative action, infants must make sense of the agent's communicative intention (Csibra, 2010) to enable inferences to the intended meaning, in accordance with the principle of relevance (Sperber & Wilson, 1995).

Recent evidence shows that surprisingly even before the end of their first year, human infants are able to ascribe and represent both the subjective motivations and episodic (or context bound) contents of epistemic states of agents of instrumental actions. There is also significant evidence indicating that preverbal infants are uniquely receptive to ostensive signals by which communicative agents make manifest that they have a communicative intention. Further evidence suggests that this evolved receptivity to ostensive signals supports an early social learning mechanism (*natural pedagogy*), whereby preverbal infants are able to interpret some of the nonverbal deictic actions and demonstrations of communicative agents as referring to a kind and displaying a property of the kind. If so, then infants can form some general deferential beliefs about the world from their interpretation of communicative agency. Clearly, this social learning mechanism could not work unless the reception of ostensive signals induced an attitude of basic epistemic trust in the infants toward their communicative informants (Gergely, Egyed, & Király, 2007).

We have two main goals in this chapter. Our first goal is to argue that much of early social cognition of human infants is shaped by the different types of inferential constraints imposed by the principle of practical rationality and the principle of relevance on interpreting acts of instrumental and communicative agency. Our second goal is to examine the scope and limits of the trust-based communicative learning system of natural pedagogy that underlies the fast intergenerational transfer of knowledge about the world by enabling human infants to acquire deferential beliefs about kinds. We shall argue that natural pedagogy enables infants to fast learn generalizations about artifact kinds. As natural pedagogy is a social cultural learning mechanism based on the principle of relevance, it may interact in subtle and complex ways with the inductive and statistical principles, which underlie belief formation based on theoretical rationality (cf. Section 4.3).

In Section 2, we review recent developmental evidence showing that young infants can represent the subjective motivations and episodic belief contents of agents of instrumental actions. In Section 3, we review the evidence showing the early sensitivity of human infants to ostensive–communicative agency and we address the puzzle of imitative learning. In Section 4, we review evidence showing the early presence of natural pedagogy as a means to learn about artifact and social kinds in human infancy. We further examine the question of how relevance-based processes at work in natural pedagogy combine with principles of statistical inference that have recently been shown to help young children learn about causal relationships.

2. THIRD-PERSONAL REASONING ABOUT INSTRUMENTAL AGENCY IN YOUNG INFANTS

Following the famous paper by Premack and Woodruff (1978), much developmental research on the ontogenesis of theory of mind in human children has focused on the emerging ability to pass the standard elicited false belief task (cf. Wimmer & Perner, 1983). In this task, a participant who knows the location of some object is asked to predict where an agent with a false belief about its location will look for it. Two decades of intense developmental research showed that not until they are in their fourth year are human children able to pass the standard false belief tasks (Wellman, Cross, & Watson, 2001).

However, starting with the seminal paper by Onishi and Baillargeon (2005), recent evidence has shown that before they reach their second year, human infants are able to ascribe epistemic states, including false beliefs, to others (see Caron, 2009; Gergely, 2010; Jacob, in press, for reviews). Exploitation of the violation-of-expectation and other paradigms has enabled developmental psychologists to reduce some of the cognitive demands that passing the standard false belief tasks required (such as language understanding, pragmatic competence and inhibitory control). Furthermore, the picture supported by our review of the recent developmental evidence is hard to square with the widespread assumption that infants start with a "simple" desire psychology before they can move to a belief–desire psychology, as was suggested by Wellman (1990) and others.

2.1. Ascribing Motivational States to Others

There is evidence that before the end of their first year, infants can track others' subjective motivations. In a series of studies applying violation-of-expectation looking paradigms, Csibra, Gergely, and collaborators have shown that infants look longer when an agent selects a less efficient instead of a more efficient action alternative as a means to achieving a goal state in the presence of some situational constraint (Csibra, Bíró, Koós, & Gergely, 2003; Csibra, Gergely, Bíró, Koós, & Brockbank, 1999; Gergely, Nádasdy, Csibra, & Bíró, 1995). Overall, the findings of Csibra and Gergely strongly suggest that infants interpret observed instrumental actions by evaluating the *efficiency* of the agent's action as a means to achieve a goal, in light of relevant situational constraints (cf. Gergely & Csibra, 2003).

In a two-object choice paradigm, Woodward (1998) showed young infants a human hand repeatedly reach for and contact one of two toys. After the locations of the toys were switched, infants looked longer when the hand reached for the new toy at the old location rather than the old toy at the new location. No such differential looking was found, however, in infants between 6 and 12 months of age if either the agent was a rigid rod or the hand approach was unfamiliar as it ended by contacting the object with the back-of-the-hand (Woodward, 1998, 1999). Woodward interpreted her findings as evidence that young infants ascribe goals only to agents whose perceptual appearance bears a strong similarity to their own bodily appearance and whose movements they can map onto their own motor repertoire. This view of goal ascription has been argued to support the widely shared assumption that, unlike inferring others' epistemic belief states, the ascription of motivational states (such as goals, intentions, or emotions) to an agent can be accomplished by cognitively less demanding automatic and noninferential processes of direct perceptual–motor matching and motor resonance induced by the perceptual similarity of the observed behaviors of others to familiar action schemes already present in the infant's motor repertoire (cf. Meltzoff, 2005; Tomasello, 1999; Rizzolatti & Craighero, 2004).

Further findings have shown, however, that neither of these conditions is necessary nor sufficient for ascribing a goal to an agent by young infants. First, Király, Jovanovic, Aschersleben, Prinz, and Gergely (2003) and Jovanovic et al. (2007) have shown that if 8- and even 6-month olds are first familiarized with one of two toys being repeatedly not only contacted but also slightly displaced by the unfamiliar back-of-the-hand action, then they look longer in the test if the back-of the-hand action displaces a novel toy at the old location instead of the same toy now at the new location. Second, Biro and Leslie (2007) have shown that if 6-month olds see a rigid rod approach one of two targets from several different angles, repeatedly pick it up by contacting three different parts of the toy (cues of equifinal variations of behavior), then they look longer if the rod performs the same action on a different target at the old location rather than on the same target at a different location. Luo and Baillargeon (2005) report a study in which 5-month olds first saw a self-propelled box repeatedly move to and contact one of two targets. During the test phase, 5-month olds looked longer when the box moved to contact the novel object at the old location rather than the old target at the new location.

These (and other) findings show that motor familiarity with the agent's action and perceptual similarity between the agent's and the infants' bodies are not necessary for interpreting an agent's action as goal directed. This is in line with studies by Gergely and Csibra (2003) that demonstrated early goal attribution even to animated abstract two-dimensional (2D) figures as long as they showed efficient goal approach. In fact, 6- and 9-month olds can interpret a wide range of unfamiliar objects (such as a robot, a box, abstract

2D figures, and even biologically impossible hand actions, see Southgate, Johnson, & Csibra, 2008) as goal-directed agents as long as their behaviors exhibit rational sensitivity to relevant changes in their situational constraints by modifying their target-directed approach contingently and in a justifiable manner obeying the principle of rational (efficient) action (Bíró & Leslie, 2007; Csibra, 2008; Csibra et al., 1999, 2003; Gergely, 2003; Gergely et al., 1995; Hernik & Southgate, 2012; Kamewari, Kato, Kanda, Ishiguro, & Hiraki, 2005; Luo & Baillargeon, 2005; Wagner & Carey, 2005; Southgate et al., 2008). Furthermore, the evidence shows that if in Woodward's object-choice paradigm during the familiarization trials infants see an agent repeatedly move to the same object in the absence of a competing target, then they do not look longer when the agent moves to contact a novel target at the old location rather than the old object at a new location in the test trials (Luo & Baillargeon, 2005; Hernik & Southgate, 2012). This strongly suggests that what Woodward's object–choice paradigm tests is not goal-ascription proper but instead the ascription of a contrastive preference (i.e. a subjective disposition) to the agent (cf. Gergely, 2010; Jacob, 2012, for further analysis).

In sum, the evidence reviewed above reveals that very young infants ascribe goals and preferences to the agent of an instrumental action. In accordance with the principle of practical rationality, the agent should be expected to execute an instrumental action that will increase the probability that she will satisfy her motivation in light of what she believes. The question arises: do infants expect an agent to perform an instrumental action, not only as a function of her motivations but also as a function of what she believes?

2.2. Ascribing Epistemic States to Others

In the last decade, a number of studies have offered new evidence that before the end of their second year, human infants are able not only to ascribe motivations to others but also to represent the contents of others' false beliefs and to ascribe to others false beliefs that they do not share. For example, Buttelmann, Carpenter, and Tomasello (2009) found that the helping behavior of 25- and 18-month olds is reliably modulated by their ability to ascribe to the agent of an unsuccessful attempt at retrieving a toy from one of two boxes either a true or a false belief about the location of the toy (for further evidence showing false belief ascription by 24- and 18-month olds, see Southgate, Senju, & Csibra, 2007 and Southgate, Chevallier, & Csibra, 2010).

Further important studies using the nonverbal violation-of-expectation looking paradigm provided initial evidence that even 13- and 15-month olds are able to ascribe false beliefs to others. In the experiment by Onishi and Baillargeon (2005), 15-month olds saw an agent motivated to find a toy and reach for it in either a green or a yellow box. Onishi and Baillargeon compared four conditions, in each of which the infants knew the true location of the toy: the infants could see the agent reach for the toy in either the green or the yellow box while the toy was either in that location or not. They found that infants looked reliably longer when they saw the agent reach for the toy either in the wrong location while she had a true belief about the toy's location or in the right location while she had a false belief. Surian, Caldi, and Sperber (2007) further reported that 13-month olds look longer at test trials in which an agent retrieves its preferred food when it is hidden from the agent's (but not the infant's) view by a high barrier than when it is visible to the agent and they also look longer when the food hidden from the agent's view by a barrier has been placed there in the agent's absence than in the agent's presence. Kovács, Téglás, and Endress (2010) provide further intriguing evidence that even 7-month olds automatically track and represent others' true and false beliefs.

Further evidence making use of the Woodward choice-based preference attribution paradigm suggests that even before the end of their first year, human infants modulate their ascription of preferences as a function of the content of the epistemic state ascribed to the agent. For example, in the familiarization trials, Luo and Baillargeon (2007) showed 12.5-month olds an agent repeatedly reach for the same object either when she knew that there was another object present or when she did not (while the two objects were visible to the infants all along). Infants looked longer when the agent selected the alternative object when it was made visible during the test phase, only if she had already known that there was another object present from having seen it put there earlier during the familiarization phase. Going one step further, Luo (2011) addressed the question whether 10-month olds would ascribe a preference to an agent when she *falsely believed* there to be either two objects or only one present. She found that 10-month olds did ascribe a preference to an agent if she mistakenly believed that two objects were present on the stage, while unbeknownst to her, a hand removed one of the objects from the side that was hidden from the agent's view but not from the infant's view. But they did not ascribe a preference to the agent when she knew that there was only one object present. Conversely, infants failed to ascribe a preference to the agent if she mistakenly believed that only one object was present on the stage, while unbeknownst to her, a human hand added on the stage a second object that was hidden from the agent's view, but not from the infants' view. Infants, however, did ascribe a preference to the agent when she knew that there were two objects present.

In all the scenarios previously reviewed showing that before the end of their first year human infants are able to ascribe false beliefs to an agent, the agent's action is directed toward some target and it depends on both the agent's epistemic state and her motivation. In the experiment by Onishi and Baillargeon (2005), the infants seem to take the agent's motivation to find an object as background information (from the familiarization trials) and they look longer in the test trials when the agent fails to act in accordance with the content of her true or false belief. Conversely, in the Woodward choice-based design exploited by Luo (2011), the infants seem to extract from the familiarization trials, as background information, the content of the agent's epistemic state as a condition for ascribing a preference to the agent and they look longer in the test trials only when the agent with a preference fails to act in accordance with it.

3. SECOND-PERSONAL UNDERSTANDING OF COMMUNICATIVE AGENCY IN YOUNG INFANTS

The evidence reviewed in Section 2 shows that young human infants can ascribe motivations and epistemic states to agents of instrumental action, in accordance with the principle of practical rationality. We now turn to developmental research demonstrating human infants' species-unique preparedness to recognize and interpret nonverbal *communicative actions* that are ostensively addressed to them. While a third-person observer expects an agent to execute an instrumental action in accordance with the principle of practical rationality, an addressee of an ostensive–communicative act expects the communicative agent to act in accordance with the principle of relevance (cf. Sperber & Wilson, 1995).

3.1. Preverbal Infants' Receptivity to Ostensive Referential Communication

Sperber and Wilson (1995) call *ostensive* stimuli the signals whereby an agent makes manifest to an addressee her communicative intention to manifest some new relevant information for the addressee (i.e. her informative intention). Right after birth, infants display species-specific sensitivity to, and preference for, some nonverbal ostensive behavioral signals, such as eye contact, infant-directed speech or motherese, and infant-contingent distal responsivity (see Csibra, 2010; Csibra & Gergely, 2009, for reviews).

Recent evidence shows that from very early on these ostensive signals generate a *referential expectation* in infants (Csibra & Gergely, 2006, 2009). Senju and Csibra (2008) report that 6-month olds followed an agent's gaze shift to one of two objects but only if it had been preceded by ostensive signals (either eye contact or infant-directed speech) addressed to the infant. In a study by Csibra and Volein (2008), after the agent produced ostensive signals, 12- and 8-month olds followed her gaze shift to one of two locations hidden from the infants' view by occluders. When the occluders were removed, an object was revealed either at the location where the agent had looked or at the other location. Infants at both ages looked longer at the empty location if the agent had looked at it than if she had not, showing that they expected the agent to look at a location occupied by a referent object rather than at an empty location. Furthermore, Deligianni, Senju, Gergely, and Csibra (2011) in an automated eye tracker-based study used an infant-induced contingent reactivity paradigm to demonstrate that 8-month olds gaze follow an unfamiliar object's bodily orientation response toward one of two targets, but only if the object had been reacting contingently before (producing self-propelled body movements such as tilting) to being looked at by the infant (see also Movellan & Watson, 2002; Johnson, Slaughter, & Carey, 1998, for similar results with 10- and 12-month olds).

Recent studies also provide converging evidence that when engaged in an ostensive–communicative interaction with an adult (such as joint play with objects), 12- and 18-month olds show early competence in drawing correct pragmatic inferences that enable them to identify the intended referent out of a number of alternative objects present when interpreting a communicator's ambiguous ostensive referential pointing gesture (e.g. Moll & Tomasello, 2004; Tomasello & Haberl, 2003). As shown by Southgate et al. (2010), in a communicative interactive context, 18-month olds can even correctly infer on pragmatic grounds the intended referent of another's false belief based pointing gesture. In this study, an adult ostensively engaged 18-month olds in a joint play activity with new toys. She placed the two novel unnamed objects in two separate boxes and then temporarily left the room. In her absence, a second experimenter switched the objects so that now they were each in opposite boxes. Shortly after, the first experimenter returned to continue their game apparently ignorant about the toys having been switched. Ostensively communicating to the infant, she pointed to one of the two (closed) boxes to request the baby to give her the toy from the box that she (falsely) believed to contain the intended object. In this communicative episodic context, infants were able to infer that the intended referent of the pointing gesture was not the object actually in the designated box, but the toy in the other box. Accordingly, they opened the *other* box (not the one the requester was pointing at) to give her the object that she meant to request by her false belief-based pointing gesture (cf. Buttelmann et al., 2009).

Furthermore, by the time they are 12-month-old, human infants are not only able to referentially understand another's communicative pointing but they also start to actively use ostensive referential pointing themselves to establish shared attention with the adult over a specific referent object to fulfill different types of communicative functions such as requesting the object from the adult (protoimperative pointing, see Bates, Camaioni, & Volterra, 1975), sharing with the adult their currently felt subjective motivational attitude toward the specific referent, such as liking and positive interest (proto-declarative pointing, see Liszkowski, Carpenter, Henning, Striano, & Tomasello, 2004; Tomasello, Carpenter, & Liszkowski, 2007), or inquiring to receive new and relevant information about the novel object and its kind (protointerrogative pointing, see Begus & Southgate, 2012; Southgate, van Maanen, & Csibra, 2007; Kovács, Tauzin, Téglás, Csibra, & Gergely, 2012).

In sum, the evidence shows that human infants are prepared from the start to recognize nonverbal ostensive referential signals and action–demonstrations addressed to them as encoding another's communicative intention to manifest new information about the referent (the informative intention) that is relevant for the addressee. As Csibra (2010) has argued, very young infants might well be in a position similar to that of a foreign addressee of a verbal communicative act, who is unable to retrieve a speaker's informative intention for lack of understanding the meaning of the speaker's utterance. Nonetheless, the foreign addressee may well recognize being the target of the speaker's communicative intention on the basis of the speaker's ostensive behavior. Furthermore, ostensive signals to which preverbal human infants have been shown to be uniquely sensitive can plausibly be said to *code* the presence of an agent's communicative intention. If so, then little (if any) further work is left for preverbal infants to infer the presence of a speaker's communicative intention after receiving ostensive signals.

Finally, in all the studies reviewed above, the communicative interactions were cooperative actions involving shared goals of immediate episodic relevance. Infants were able in such contexts to disambiguate the referent of the communicator's nonverbal deictic referential action, even when the deictic gesture was based on false belief (about, e.g., the location of the intended referent). Crucially, in the episodic context of joint actions where communicator and addressee have shared goals and common knowledge about a restricted set of relevant familiar individual objects, nonverbal deictic pointing owes its referential success to the fact that it directs the other's attention to the particular intended referent by highlighting its *spatial location* (which is one of its typically transient and episodic properties). The fact that nonverbal deictic gestures are anchored in a socially shared episodic context seems to impose severe restrictions on their referential scope—a limitation emphasized by Tomasello (2008) when he points out that "the almost complete dependence of pointing on common ground between communicator and recipient is thus both its strength and its weakness" (pp. 202–203).

However, in apparent contrast to this assumption, a recent study by Egyed, Király, and Gergely (2012) demonstrates the special power of ostensive signals to induce a *nonepisodic* interpretation of a communicative agent's object-directed emotion gestures as conveying relevant information about motivational dispositional properties such as *preferences that are socially shared* and, as such, can be generalized and attributed to other agents who are not part of the shared episodic context. 18-month olds saw an adult agent display a positive and a negative object-directed facial–vocal emotional expression (liking vs. disgust), one directed toward a novel object on her left, the other toward another unfamiliar object on her right. In the ostensive–communicative condition, before displaying her object-directed emotional expressions, the agent first ostensively addressed the infant. In the noncommunicative demonstration context, the agent neither looked at nor talked to the infant before displaying her pair of object-directed emotion expressions. After the first agent left the room, a new agent came in and without looking at either object, she requested the infant to give her one of them. In the ostensive–communicative condition, but *not* in the noncommunicative observation condition, infants reliably gave to the second agent the object toward which the first experimenter had emoted positively. Finally, in the noncommunicative condition, infants reliably gave to the first agent the object that had been the target of her own positive emotional expression. In the latter case, the application of the principle of practical rationality to an object-directed action would require the ascription to the agent of a person-specific subjective motivational state of contrastive preference for one over the other of the two objects. Application of the principle of relevance triggered by the presence of ostensive cues, however, induced in infants the assumption that the relevance of the contrastive preference displayed toward the two objects *goes beyond the episodic situation* and demonstrates a socially shared dispositional property that can be relevantly *generalized* to other members of one's social group as well.

3.2. A Puzzle about Imitative Learning

A number of psychologists, including Tomasello and colleagues, have taken imitation to be a process that both complies with the principle of practical rationality and also underlies cultural learning, i.e. the intergenerational transmission of cultural knowledge (cf. Tomasello, 1996, 1999; Tomasello, Kruger, & Ratner, 1993; Tomasello, Carpenter, Call, Behne, & Moll, 2005; Buttelmann, Carpenter, Call, & Tomasello, 2007). In particular, Tomasello et al. (1993) have hypothesized that, unlike blind mimicry, *true* imitation requires the imitator to construe the agent's intention as a rational choice of an action plan, i.e. as an efficient means toward achieving her goal, in accordance with the principle of practical rationality. The question is: to what extent can the rational imitation model account for imitative learning, i.e. human children's ability to interpret and reproduce an agent's selection of some novel action as a means to achieving her goal. As Gergely, Bekkering, and Király (2002) have noticed, the question is made pressing by Meltzoff's (1988) study in which 14-month olds observed an adult model perform an unusual head action whereby she turned on a magic light box by leaning forward and applying her forehead to the box. Meltzoff (1988) reports that after a week delay, 67% of the infants who had watched it imitatively reproduced the agent's odd head action. On the face of it, this result is a puzzle for the rational imitation approach because the model's head action can hardly be evaluated as an efficient means to achieve the goal of turning the light on.

To address this puzzle, Gergely et al. (2002) had 14-month olds watch a model perform the odd head action as a means to switching on a light box in one of two contexts: in the hands-occupied context, the model first pretended that she was chilly, covered her shoulders with a blanket, and used her hands to hold the blanket around her shoulders, before demonstrating the odd head action. In the hands-free context, she also pretended to be chilly, covered her shoulders with a blanket, and tied a knot on it thereby freeing her hands, which she ostensibly placed unoccupied on the table, before demonstrating the odd head action. Gergely et al. (2002) found that while in the hands-free context, 69% of the children replicated the odd head action, in the hands-occupied condition, only 21% of them did. Instead, in the hands-occupied context, infants freely used their own hands. (For further confirmation of the influence of social communicative contexts on selective imitation in 12- and 14-month olds, cf. Buttelmann, Carpenter, Call, & Tomasello, 2008; Király, 2009; Király, Csibra, & Gergely, 2004; Király, Csibra, & Gergely, 2012, Király, Egyed, & Gergely, 2012; Schwier, van Maanen, Carpenter, & Tomasello, 2006; Zmyj, Daum, & Aschersleben, 2009.)

While the model's choice of the head action seems rational in the hands-occupied context, so does the infants' choice to (nonimitatively) emulate the agent's goal by selecting a more efficient means action available to them (whose hands were unoccupied). So far this is in accordance with the rational imitation model, which assumes "that infants take into account the constraints on the demonstrator—the reasons why she acted the way she did—as well as the constraints on themselves and then choose an action themselves rationally" (Buttelmann et al., 2008, p. 625).

But the puzzle is: why did the majority of infants reenact the experimenter's odd head action in the hands-free context when both the model and the infant could have used their own free hands and thereby select a more efficient means?[1] In answer to this question, Tomasello and colleagues have proposed a slightly different version of the rational imitation model: they have surmised that the more an agent's action is construed as displaying the *freedom* of the agent's choice, the more the infants are likely to reproduce the model's action. Arguably, the agent's selection of the head action as a means to switching on the light box reflects the infant's sensitivity to the agent's freedom of choice in the hands-free condition, where her decision to perform the odd head action was less constrained by the external circumstances than in the hands-occupied condition (cf. Buttelmann et al., 2007). On this version of the rational imitation model (as well as on the initial "rational imitation" hypothesis by Gergely et al., 2002), infants reproduced the agent's unexpected head action as a way of figuring (learning) what the agent's reason for his action was.

3.3. Solving the Puzzle about Imitative Learning

If, however, the agent's goal is to switch on the light, then there is no way that by performing the head action (rather than by using their own hands),

[1] In fact, in the hands-free context, all infants performed at least one (and typically more) nonimitative hand actions to emulate the goal by using their hand to touch the light box before reenacting the odd head action (cf. Gergely et al., 2002; Király, Csibra, & Gergely, 2012; Király, Egyed, & Gergely, 2012; Paulus, Hunnius, Vissers, & Bekkering, 2011).

an imitator could discover to what extent it is an efficient means to achieve the agent's goal, in accordance with the principle of practical rationality. Nor could performing the head action allow an imitator to discover to what extent the head action is a more efficient means to achieve the agent's goal in the hands-free than in the hands-occupied context. But infants imitated the head action far more often in the hands-free than in the hands-occupied context. Furthermore, as Gergely and Csibra (2005, 2006) have pointed out, no version of the rational imitation model could explain the later findings of Király, Csibra, & Gergely (2012; Király, Egyed, & Gergely, 2012; Király et al. 2004) showing that only when the head-touch actions are demonstrated by a communicative agent addressing the infants from a second-person perspective by ostensive referential gestures did infants selectively imitate the head action more in the hands-free than in the hands-occupied context. In fact, when infants observed a noncommunicative agent perform the head-touch actions in the hands-free condition, they tended not to reproduce the head action at all showing significantly less head-touch reenactment than in the corresponding hands-free context of the communicative demonstration condition.[2] Other studies also found that the presence of social communicative demonstration context exerts a powerful modulating effect on imitative reenactment inducing selective imitation in ostensive contexts with much reduced imitation of the same actions observed in third-person noncommunicative contexts (cf. Brugger, Lariviere, Mumme, & Bushnell, 2007; Király, 2009; Nielsen, 2006; Southgate, Chevallier, & Csibra, 2009).

Following Gergely and Csibra (2005, 2006) and Király, Csibra, & Gergely (2012; Király, Egyed, & Gergely, 2012; Király et al., 2004), we therefore suggest that the mistaken assumption made by advocates of the rational imitation model is that even when they are provided with ostensive cues, infants interpret the agent's head action as an instrumental action to be performed in accordance with the principle of practical rationality. If addressed by ostensive signals, infants do not stand to the agent's head action as third-personal observers of an instrumental action. Instead, the reception of ostensive cues automatically causes the infants to assume that the agent is performing a communicative action, and they interpret the agent's action demonstration from an addressee's second-personal perspective. As a result, they expect the communicative agent to demonstrate for them something

[2] This finding has recently been replicated using a modified procedure by Király, Egyed, & Gergely (2012), in response to a potential methodological criticism by Paulus et al. (2011).

novel and relevant to be reproduced, in accordance with the principle of relevance.

Following her production of ostensive cues, in the hands-occupied context, the model first demonstrated to the infants that her hands were occupied with holding the blanket covering her shoulders when she proceeded to perform the odd head action to illuminate the touch-sensitive lamp in front of her. What the infants therefore learnt from the model's head action was that the unfamiliar artifact on the table is a lamp that can be operated by contact and that they could (and ought to) turn on the lamp by making contact with it using an instrumental action appropriate for the purpose. But in the hands-free context, after having tied a knot on the blanket, the demonstrator conspicuously placed her now free hands at rest next to the touch-lamp calling the infants' attention to the relevance of the fact that her hands are now available for alternative instrumental use. What the infants therefore learnt from the model's head action was that they could (and ought to) turn on the light box by applying their head, instead of their hands. In brief, infants apparently interpreted the agent's ostensive signals as cues indicating a pedagogical context and so they learnt to perform the odd head action, thereby acquiring a deferential belief about the normative manner or social expectation as to how one "ought to" operate the touch lamp. This finding further suggests that the process whereby infants learnt to perform the odd head action was not based on the assumption that this action was the most efficient causal alternative to bring about the effect. Instead, they may have encoded the demonstrated head action as socially relevant shared knowledge about a normatively expected way of executing the skill.

4. ENDURING RELEVANCE AND RATIONALITY

Since relevance is a property of a communicative action, it must be recognized as such by the recipient of the communication to whom it is ostensively addressed (i.e. from a second-person perspective). Practical rationality is a property of an agent's decision to perform a particular instrumental action to achieve her episodic goal, in the most efficient manner available. This property is recognized by the interpreter observing the instrumental action from a third-person perspective inducing the expectation that the action chosen by the agent will be the most efficient one to enable her to fulfill her desire in the light of her beliefs. An agent's belief is taken to be theoretically rational when its content stands in deductive or inductive relations to the contents of other accepted beliefs, which warrant its acceptance. The warrant underlying the theoretical rationality of beliefs can also be computed from a third-person perspective. Inductive learning is the process whereby humans in general and human children in particular form new beliefs and update their older beliefs. In what follows, we shall examine novel evidence showing how an addressee's presumption of the relevance of an agent's communicative action can considerably support inductive learning in human infancy.

4.1. The Puzzle of Deictic Reference to Kinds

While experiments reviewed in Section 3.1 show that preverbal human infants are able to disambiguate the intended referents of deictic pointing in the episodic context of joint actions, further experiments indicate that the reception of ostensive signals can also prepare preverbal human infants to receive *nonepisodic* information about the referent of an agent's communicative action. The study by Egyed et al. (2012) on preference attribution discussed at the end of Section 3.1 above provided a first example of this phenomenon (cf. Gergely et al., 2007). Here, we shall review further recent studies showing that when ostensively cued in an appropriate nonfamiliar context, infants can interpret an agent's deictic referential action as intended to refer to a kind, not merely an individual. Since deictic reference performed by pointing by its very nature individuates its referent by highlighting its spatial position (which is a transient and episodic property of particular objects), this raises the puzzle of deictic reference to kinds.

In fact, the evidence suggests that the reception of ostensive signals can trigger in infants two broad kinds of expectation about an agent's subsequent nonverbal communicative action. In the context of a joint (cooperative or competitive) action, in which agents have a shared episodic goal and share common knowledge about a restricted set of familiar objects and the surrounding situational constraints, infants have been shown to expect a communicative agent to convey relevant episodic information (Tomasello, 2008). In such contexts, the reception of ostensive signals generates an expectation of *local* relevance: infants' expectation of local relevance enables them to determine the intended referent of the communicator's deictic referential act required for fulfilling the shared episodic goal. As the discussion of imitative learning showed, however, lacking the context of a shared episodic goal and a set of familiar objects, however, the reception of ostensive signals triggers a presumption of *enduring* relevance. As we shall now argue, when ostensively cued in the presence of novel unfamiliar objects, infants expect to be taught relevant nonepisodic information about kinds. They expect the communicator's referential action to apply to a kind (not an object) and her subsequent demonstration to display a nonepisodic (or enduring) property of the kind.

In a study by Yoon, Johnson, and Csibra (2008) about change detection in a communicative or a noncommunicative context, 9-month olds saw an object which was either the target of an agent's instrumental (noncommunicative) reaching action or was demonstrated by the agent's communicative act using referential pointing ostensively addressed to the infant. Then a screen came down to briefly occlude the object which either changed it's spatial position or its visual features before being revealed to the infant again. Infants looked longer at a change of the object's location than at a change of the object's visual features in the noncommunicative instrumental action condition but they showed the opposite looking pattern in the communicative action condition. Clearly, while a target's temporary location is relevant to predicting and explaining an agent's instrumental action directed to it, the visual features of the object highlighted by the ostensive referential pointing gesture are more likely to be nonepisodic properties relevant for reidentifying it under new circumstances, learning about its kind and classifying it under a sortal concept.

Years ago, Piaget (1954) reported the classical A-not-B *perseveration* error phenomenon whereby infants between 8 and 12 months are engaged in an episodic hide-and-search game in which an adult repeatedly hides a toy under one (A) of two opaque containers (A and B) in full view of the infant. After each hiding event, the infant is allowed to retrieve the object. During test trials where the demonstrator places the object repeatedly under container B, infants continue to perseveratively search for it under container A where it had been previously hidden. Topál, Gergely, Miklósi, Erdőhegyi, and Csibra (2008) compared three conditions. In the first communicative condition, 10-month olds received ostensive signals before and while the adult played the hide-and-search game. In the second noncommunicative condition, the agent presented the hiding actions without any ostensive signals directed to the infant. In the third nonsocial condition, the agent was hidden behind a curtain while her hands were baiting the containers, and therefore, she was not visible to the infants at all. Topál et al. (2008) report that 86% of the infants committed the A-not-B perseverative error in the communicative condition (replicating previous findings), but this error rate sharply dropped in the noncommunicative and the nonsocial conditions. Topál et al. (2008) argue that when they fall under the spell of ostensive–communicative signals, 10-month olds are fooled into misinterpreting the episodic hide-and-search game as being a communicative teaching demonstration about some nonepisodic property—exemplified by the manifested action—that relates the toy and one of a pair of containers spatially individuated by the demonstrator's deictic referential actions. In sum, while hiding events in the standard A-not-B task can be (and has been) interpreted as conveying episodic information about the referent's current location ("the target object is now under container A"), these results suggest that due to the presence of ostensive signals, infants interpreted them as communicative actions manifesting relevant information for them to acquire about some generalizable normative property of the referent kind (e.g. "Container A is where this (kind of) object belongs to/should be placed in/should be looked for", see also Topál, Gergely, Erdőhegyi, Csibra, & Miklósi, 2009).

While the evidence reviewed so far indicates that the presence of ostensive cues generates referential expectations in preverbal human infants, further evidence shows that ostensive signals also cause infants to expect a communicative agent's display of an object to refer to a *kind*. Futó, Téglás, Csibra, and Gergely (2010) exploited the object-individuation paradigm by Xu and Carey (1996) to investigate the ability of 10-month olds to represent objects in terms of their kinds. After infants were familiarized to seeing two distinct objects (e.g. a truck and a teddy bear) emerge one at a time from behind a screen and never simultaneously, the screen was removed, and infants either saw the two objects or only one. Xu and Carey (1996) reported that while 12-month olds looked longer when they saw only one object, 10-month olds looked equally at the two events. In other words, 10-month olds did not yet rely on feature-based information to individuate objects in this task. Further evidence showed that when each of the two objects were named by one of two distinct verbal labels when separately visible, even 9-month olds looked longer at the single object event than at the two objects event (Xu, 2002, 2005, 2007).

The goal of the three experiments by Futó et al. (2010) was to test whether communicative ostensive signals could play the same role as verbal labeling in enabling 10-month olds to rely on property information in an object-individuation task. In the first experiment, the selected objects were two novel artifacts, one with a handle and the other with a dial, and the relevant properties to be displayed by the agent's nonverbal communicative actions were kind-relevant functional properties. In the communicative function demonstration condition, before receiving two familiarization trials, 10-month olds were first ostensively greeted by infant-directed speech (while the artifacts were still hidden behind the screen). During the familiarization trials, the infants saw the agent, which was a human hand, separately display each artifact on either one or the other side of the screen and perform a different function demonstration on each of them: the hand pulled the handle on one artifact, which produced flashes of light as a result, or turned the dial on the other artifact, which produced a melodic sound effect. Finally, the hand pulled back each of the objects behind the screen. After two such familiarization trials, the infants received two test trials: while the first was identical to the familiarization trials, during the second, the hand removed the screen and revealed either both of the objects or only one. Infants looked reliably longer when only one object was revealed rather than two.

In a second experiment, Futó et al., (2010) removed one of two parameters: in the non-ostensive condition, infants heard a synthesized nonspeech sound transform of the original ostensive greeting in infant-directed speech before the familiarization trials. In the no-intervention condition, the hand that had pulled out the objects from behind the screen withdrew from sight without performing the function demonstration on them, and infants instead saw either the handle or the dial move by itself while the object was simultaneously emitting either light or sound. Infants looked equally long at the one-object and at the two-object events in the test trials in both the non-ostensive and the no-intervention conditions.

In a third experiment, Futó et al., (2010) reproduced the familiarization and test trials of the first experiment (with ostensive greeting and manual intervention present). However, instead of using two distinct novel artifacts, the very same single artifact was presented on each side, which, however, had two instead of just one manipulanda protruding from it (a handle and a dial). So the two different function demonstrations by the hand producing either the light or the sound effect were demonstrated on the same artifact in alternation, at either side of the screen. Infants looked longer in the test trials when they saw the same single object (with both the dial and the handle) than when they saw two distinct novel objects (neither of which they had seen during familiarization), one with only a handle and the other with only a dial on it.

In the first experiment, infants took the communicative agent to be referring to a kind of artifact and they interpreted the agent's subsequent manual demonstration of the function of the object to display a generic (nonepisodic) functional property of the kind in question. (This is the puzzle of deictic reference to kinds.) They must have further assumed that two distinct functional properties such as producing a light versus a sound upon manipulation could not serve at the same time as kind-defining properties of a single kind of artifact. As a result, they looked longer when they saw only one object rather than two in the test trials. In other words, if preceded by ostensive cues, then an agent's referential action and communicative demonstration were interpreted by the 10-month olds as manifesting kind-specifying functional properties leading them to infer the presence of *two* different artifact kinds that the referent objects must have belonged to.

In the second experiment, lack of ostensive cues failed to trigger the expectation that the agent's deictic demonstrative actions would make reference to kinds rather than referring to an individual object. So even though the hand demonstrated two different actions resulting in alternative effects on the two objects, infants did not interpret these demonstrations as referring to two separate artifact kinds. As a result, they looked equally long when seeing one versus two objects present behind the screen during the test. In the no-manual intervention condition, the handle and the dial on the artifacts were shown to move on their own simultaneously producing light versus sound. Here, infants could not interpret these contingent behaviors as functional properties, and so in spite of the preceding ostensive signals, they could not make sense of the agent's referential action as referring to a kind of artifact, in the absence of a subsequent manual action–demonstration that could have identified the predicated artifact function.

Furthermore, the third experiment suggests that the infants were so strongly cued toward interpreting the agent's communicative action as referring to a kind that when the agent demonstrated that a single artifact could produce both light and a sound, they were fooled into assuming that only two distinct kinds could exhibit two distinct functional properties. This is shown by the fact that they looked longer when seeing during test the single object that they had seen during the familiarization events than when seeing two novel objects whose features only partially matched those of the one seen during familiarization.

Assuming that infants are able to represent the content of a communicative intention (as we argued in Section 3.1 that they are), then they should expect the nonverbal action of a communicative agent to be relevant. Furthermore, what the above findings suggest is that, in the presence of ostensive signals, an agent's referential action and demonstration upon a novel object and/or property cue infants' expectation of relevance: infants expect the information conveyed by the communicative agent to be about enduring properties of an artifact *kind*. *Natural pedagogy* is the name given by

Csibra and Gergely (2009) to the social learning mechanism enabling infants to acquire kind-wide generalizations on the basis of their interpretation of the ostensive nonverbal referential actions and demonstrations of communicative agents. In the presence of ostensive signals, an agent's referential action and demonstration are interpreted as displaying the property of a kind (i.e. as teaching a kind-wide generalization).

Clearly, preverbal human infants have no means at their disposal for assessing the trustworthiness of their informants. Consequently, general deferential beliefs about kinds formed by preverbal human infants can only be based on blindly trusting their informants. New evidence suggests both that natural pedagogy enables preverbal human infants to acquire generalizations about kinds of artifacts and also that the essentialist bias documented in young children's concepts of natural kinds extends to their concepts of artifact kinds.

4.2. The Scope of Psychological Essentialism in Infancy

Essentialism is the idea that entities of various kinds have essential causal properties which are not directly observable but are responsible for the observable features of the entities that bear them. Psychological essentialism is the view accepted by many psychologists that essentialism underlies human children's conceptual development in various cognitive domains. The essential property is construed as a "causal placeholder" (Gopnik & Nazzi, 2003). While developmental psychologists have adduced much evidence for psychological essentialism in early childhood with respect to physical, chemical, and especially biological kinds (Gelman, 2003), it has been also argued that naive essentialism is likely to be domain specific being restricted to young children's natural kind concepts, and that it initially does not apply to their understanding of artifacts (e. g., Brandone & Gelman, 2009). But as we shall first argue in this section, very recent evidence suggests that preverbal infants are prone to interpret nonverbal referential actions in accordance with psychological essentialist assumptions about artifact kinds as well (Futó et al., 2010).

The findings by Futó et al., (2010) strongly suggest that preverbal infants can learn generalizations about artifact kinds from a sequence of nonverbal actions performed by a communicative agent. As philosophers and psychologists have emphasized, to categorize objects into *kinds* is to assume that they share some common unknown unobservable underlying properties that cause them to have superficial observable properties that can be perceptually detected. As a result, one should not expect the truth of a generalization about some property of a kind to be easily dismissed by negative evidence based on the superficial observable properties of objects falling under the relevant kind. This is exactly what a recent experiment with older children shows.

In a study by Butler and Markman (2012), 4-year olds were presented with 11 wooden blocks and taught their name, i.e. 'blicket'. Only 1 out of 11 blickets had a (nonvisible) magnetic tape on one end. Then the children were shown the novel property of the magnetic blicket: by applying the blicket with magnetic tape to paper clips, the experimenter picked up the paper clips, in three distinct conditions. In the pedagogical condition, the children were informed that they would be taught something novel and interesting before the magnetic property of the blicket was demonstrated. In the accidental condition, the experimenter accidentally dropped the magnetic blicket onto the paper clips. In the intentional condition, the experimenter deliberately placed the magnetic blicket onto the paper clips without, however, ostensively addressing the infants. In all three conditions, after her demonstration, the experimenter placed all 11 blickets on the table and encouraged the children to play with them. Butler and Markman (2012) found that children's persistence in exploring the magnetic property of blickets in the face of mounting negative evidence (that they themselves generated as they were trying out the rest of the non-magnetic blickets in front of them) was remarkably stronger in the pedagogical than in either the accidental or the intentional condition.

Arguably, this study shows that in the pedagogical condition (and only in this condition), children took the generalization about the magnetic property of blickets to have generic content, i.e. they took the demonstrated magnetic property of blickets to be a property of a kind of objects. If resistance to counterevidence is taken as a signature of the generic content of kind-wide generalizations, then one may interpret 10-month olds' perseveration in the A-not-B task investigated by Topál et al. (2008, 2009) as providing such evidence. In the ostensive–communicative condition of that study, the high rate of erroneous perseverative search under the (now empty) container A during the B-hiding trials did not decrease across the three B trials even though these provided clear cases of counterevidence. Infants may have interpreted the A-hiding demonstration as displaying a relevant property of the kind of action executed (placing the toys into container A) and thereby carrying social normative implications, which were violated but not modified by the B-hiding events. This signature of kind-wide generalizations seems also displayed by 14-month olds' selective imitative learning of novel means as demonstrated by Gergely et al. (2002).

In response to the ostensively demonstrated model's head action, the infants' strong inclination to reenact this opaque, odd, and apparently nonrational means action (in the hands-free context) was quite uninhibited by the availability of the negative evidence, which infants spontaneously produced by concomitantly performing hand actions that successfully turned the light box on in a more efficient way.

Leslie (2007) has argued that generics in natural languages ("birds fly"), which contain no explicitly encoded quantifiers, have peculiar semantic properties that make them strongly resistant to counterevidence and furthermore that humans are biased toward making kind-wide generalizations with such a peculiar generic content. Arguably, the causal essentialist construal of kinds can provide an explanation for why generalizations about kinds should not be easily dismissed by putative negative evidence based on the observable features of instances of kinds. In the case of natural kinds, for example, according to biological essentialism, it is in the biological nature of tigers to be striped, a tiger that fails to be striped is a defective tiger, but it is not a counterexample to the essentialist claim that being striped is caused by some unknown essential biological property of tigers (cf. Atran, 1990). While being striped (which is observable) is taken to be caused by some biological unobservable essential property of tigers, it is *not* itself an essential biological property of tigers. Conversely, being deprived of observable stripes is not counterevidence to the presumed presence of an underlying essential biological property that causes tigers to be striped in *normal* conditions.

What the evidence previously reviewed shows is that young children also make essentialist assumptions about *artifact* and *social* kinds. Furthermore, it also shows that preverbal human infants can learn generalizations about artifact and social kinds from the nonverbal actions of communicative agents. Nonverbal demonstrations seem well suited for conveying generic (nonepisodic) information about artifact kinds as well as some social kinds. For example, in the experiments by Futó et al., (2010), the two-step communicative action involved a pair of referential act and a demonstration whose function was to display the property predicated of the ostensively referred kind of artifact (e.g. produce either a melodic sound or a flash of light). Arguably, the essentialist construal of artifact and social kinds by preverbal human infants is promoted by their irresistible tendency to epistemically trust their communicative informants. Because they accept the information conveyed by communicative agents on trust, infants might assume not merely that the observable features of man-made tools and human actions and practices demonstrated to them are caused by some deep underlying essential properties, but that they *must* be so caused. Why should trustworthy informants take the trouble to display the properties of artifact and/or social kinds by means of their nonverbal communicative actions for infants' benefit if they did not thereby convey either the functional properties of *normal* (i.e. non-defective) artifacts or the *norms* with which the actions of human agents *ought* to comply? Furthermore, the ascription of functions to both natural and artifact kinds involves or carries *normality* assumptions. Just as it is the function of a normal mammalian heart to pump blood, it is also the function of a normal chair to afford the possibility of sitting on it. A mammalian heart that fails to pump blood is a defective heart whose biological function is to pump blood. Even if poorly designed (or damaged), a chair has the (intended) function to enable humans to sit on it.[3]

As emphasized by Csibra and Gergely (2006), human infants are borne into a world populated with man-made artefacts whose causal and functional properties as well as appropriate manner of use are epistemically larely opaque to them. This epistemic opacity may encourage infants to assume, in accordance with the essentialist bias, that the surface-observable properties of man-made tools result from their underlying essential properties (e.g. their intended function). This could provide a further reason for why the essentialist bias in young human children extends to artifact kinds.

Finally, normality assumptions are also carried by ascriptions of functional properties to social kinds: if an individual fails to comply with social norms (e.g. take his hat off his head as he walks into a church), we take the individual's behavior to be defective (or the individual to defect from the relevant norms), not to be a counterexample to the veracity of the social norms. Arguably, the findings by Gergely et al. (2002) on imitative learning and by Topál et al. (2008, 2009) on the A-not-B task show how the reception of ostensive signals cues human infants into interpreting an episodic demonstration as a teaching session from which they learn a social *norm* about either how to act in the presence of a novel artifact or which of a pair of containers is supposed to contain a toy.

[3] Millikan (1984, 1993) and Neander (1995) have stressed the pervasiveness of *normality* assumptions in the ascription of functional properties to biological kinds and the non-prescriptive *normative* implications of the ascription of functional properties to biological kinds. Of course, this unified view of the ascription of functional properties (to natural and artifact kinds) builds on a scientific Darwinian view of biological functions, which should not be imputed to preverbal human infants.

4.3. Natural Pedagogy and Bayesian Inductive Learning

In this final section, we turn to recent probabilistic Bayesian computational models of rational causal inductive learning that emphasize human infants' remarkable sensitivity to statistical patterns of evidence as the primary basis for constructing coherent, abstract, and causal representations of the world in different knowledge domains. Some recent Bayesian computational models of statistical inductive inferences in young children provide clear evidence for the power of ostensive pedagogical demonstrations in inducing, informing, and constraining the scope of inductive inferential generalizations drawn by preschoolers. For example, Bonawitz et al. (2011) have argued that "children are more likely both to learn demonstrated material and to generalize it to novel contexts in teaching than in non-teaching situations" (p. 326), in accordance with the natural pedagogy approach. Buchsbaum, Gopnik, Griffiths, and Shafto (2011) have also showed that a demonstrator's pedagogical stance has a significant effect on children's decisions whether to imitate part or all action sequences demonstrated to them.

Several recent studies, however, provide suggestive evidence that even much younger infants seem to possess sensitivity to purely statistical information that entails random versus selective sampling by an agent and that they can rely on such statistical information to spontaneously constrain the kind of inferential generalizations they draw from the observed evidence (e.g. Gweon, Tenenbaum, & Schulz, 2010; Ma & Xu, 2011; Kushnir, Xu, & Wellman, 2010). For example, Gweon et al. (2010) argued that different inferences are licensed if samples are drawn randomly from the whole population (*weak sampling*, i.e. an agent chooses items at random from the population, independent of their properties) than if they are drawn selectively only from the property's extension (*strong sampling*, i.e. the agent samples items selectively, depending on their relevant properties). As they point out, "weak sampling provides a less powerful constraint on induction (as both positive and negative evidence will be necessary to constrain inferences generalizing to subpopulations)," while "even a few samples of positive evidence … can constrain inductive generalizations to subpopulations or kinds" (p. 9066) under the assumption of strong sampling by the agent.

In a series of elegant studies, Gweon et al. (2010) explored the hypothesis that there may be "early constraints on what infants assume about rational agents' sampling processes" (p. 9066). In one study, 15-month olds watched as an adult glanced into a transparent box in front of them (containing a population of blue and yellow balls), pulled out a blue ball, squeezed it so that it squeaked, and then set it on the table. The experimenter repeated this until she pulled out the sample of blue balls (three, two, or just one) tested in the given conditions. Then, after a brief pause, she went on to pull out a yellow ball and put it in front of the child saying, "Here you go, you can go ahead and play." Across different (random vs. selective) sampling conditions, infants saw exactly the same sequence of demonstrations while the distribution of the population from which the agent sampled the balls was varied in a way that was transparent to the infants. For example, in a random sampling condition, a sequence of three blue balls were sampled from a transparent box which (visibly to the infant) contained a majority (75%) of blue and only a minority (25%) of yellow balls, while in the strong sampling condition the three blue balls were drawn identically but this time from a transparent box that contained only a minority (25%) of blue balls and 75% of yellow balls. The question of interest was the degree to which infants would differentially generalize the object property (makes sound if squeezed) demonstrated on the three sampled blue balls to the yellow ball as a function of their evaluation of the difference between the sampling conditions. The results showed that while infants constrained their generalization of the squeaking property to the blue balls in the strong sampling condition (with only 33% of them squeezing the yellow ball), they did not do so in the random sampling condition (where 80% tried to squeeze the yellow ball). Based on such results, the authors conclude that "in the absence of behavioral cues to the sampling process, infants make inferences consistent with the use of strong sampling." Thus, they argue that "infants make accurate generalizations from sparse data, in part because their inferences are sensitive to how the sample of evidence reflects the population" (p. 9071).

Other recent studies based on the Bayesian approach have explored the use of statistical evidence in rational inferences about the social world (see Ma & Xu, 2011; Kushnir et al., 2010). For example, Ma & Xu (2011) raised the intriguing question "whether young children can use statistical patterns in the choices that other people make to infer the subjective nature of mental states" (p. 410). They point out that "as a source of motivation that enables an agent's choice of one option over another, preferences are subjective and often person-specific—different people can have different attitudes toward the same entity" (p. 403). In their study, they explored, therefore, whether toddlers can make use of purely statistical sampling evidence as a basis for ascribing to others person-specific subjective preferences different from their own. First, in a baseline condition, the experimenter presented 2-year olds and 16-month olds with two bowls each containing one of two kinds of objects (either boring or interesting toys only). The infants were then asked: "Which one do you like to play with? Just choose one!" The toddlers' choices were taken to indicate their own subjective preference (in fact, most expressed preference for the interesting toys). Second, to assess the infants' prior beliefs about the experimenter's subjective preference, the adult placed one hand, palm facing up, between the two bowls and asked the child: "I like to have a toy to play with. Can I have the one I like?" In general, infants relied on their own preference when judging the experimenter's likely subjective preference: they tended to give her the same kind of (interesting) toy that they themselves had shown a preference for. Third, toddlers saw the adult sample six boring objects in three conditions. In the nonrandom sampling condition, the adult drew six boring objects from a transparent jar containing only 13% boring objects and 87% interesting ones. In one of the random sampling condition (without alternative), the adult drew six boring objects again this time, however, from a transparent jar containing 100% boring objects. In the random sampling condition with an alternative, the adult drew the six boring objects from a transparent jar containing 88% boring objects and only 12% interesting ones. This was followed by a test phase to examine whether the sampling information would affect children's judgment of the experimenter's preference. Immediately after the sampling event, the experimenter asked children about her own subjective preference a second time: "I like to have a toy to play with. Can I have the one I like?" The toddlers' choice of toy to offer from the two bowls (boring or interesting toy) was interpreted as reflecting the person-specific subjective preference that the infant ascribed to the adult (as a function of her previously observed sampling behavior). Ma and Xu (2011) report that 2-year olds used the nonrandom sampling as a cue to the agent's current subjective preference (i.e. for the boring objects), while in both versions of the random sampling condition, they continued to rely on their own preference as the basis for judging the agent's likely preference. The authors report a weaker but similar effect in 16-month olds as well. Based on these results, they conclude "that by age 2 children apprehend the subjectivity of preferences based on sampling evidence alone, in the absence of social-pragmatic cues" (p. 410).

In sum, the studies reviewed above provide intriguing new evidence that when learning from the observed actions of intentional agents human infants show sensitivity to statistical information that is compatible with the assumption of strong sampling by the agent and can rely on such information to induce fast learning as well as to constrain the referential scope of projected inductive generalizations to kinds. The evidence also indicates that the assumption of strong sampling is applied to drive rational inferential learning about different aspects of the physical and social world already by 15- and 20-month-old infant observers (in contrast to conditions where the same evidence is interpreted as involving random sampling).

The core theoretical assumption behind the Bayesian research program of rational inductive learning is the proposal that the early constraints on what infants assume about agents' sampling processes reflect a central property of rational instrumental agency. As Gweon et al. (2010) put it, "considerable work suggests that infants make assumptions about rational agents with respect to intentional goal-directed actions (Gergely & Csibra, 2003; Gergely et al., 1995; Woodward, 1998)" (p. 9070). While they further argue that "it would be very interesting if the assumption that agents were likely to engage in selective sampling were part of this repertoire" (p. 9070), they refer to the body of evidence (reviewed in Section 2) showing that infants expect agents of instrumental actions to choose the most efficient means action available to them to achieve their goal, in accordance with the principle of practical rationality. Is this core assumption correct?

We doubt it on two grounds. On the one hand, we have argued that practical rationality is restricted to the third-person interpretation of the instrumental actions of goal-directed agents and to their expectable choice of efficient means actions to bring about their episodic goals in the world. On the other hand, much evidence reviewed above in this paper shows that infants learn to make generalizations about social and artifact kinds from a second-person perspective from communicative actions addressed to them, while they fail to do so when they observe from a third-person perspective the very same actions performed by a noncommunicative agent. For example, in studies on selective imitative learning of novel means actions, 14-month olds were provided with the same statistical evidence when they observed an adult perform three times in a row an odd and unfamiliar "head action" to contact and illuminate a novel touch-sensitive lamp in the hands-free condition either by a communicative agent ostensively addressing them or by a noncommunicative agent observed from a third-person perspective. The infants only learnt to perform the odd head action in the former but not in the latter condition (Király, Csibra & Gergely, 2012). In the object-individuation study of Futó et al., (2010), 10-month olds were provided with the same statistical evidence in either a communicative or a noncommunicative action–demonstration condition involving six repeated function demonstrations of each of two novel functions on two different artifacts, respectively. While the demonstrations provided sufficient statistical information of positive evidence to support inductive generalization of the functional property to the artifact kind, infants showed evidence of kind assignment only in the communicative ostensive demonstration context. On this basis, we surmise that infants take strong sampling as part of communicative, not instrumental, agency. We further think that both the studies of Gweon et al. (2010) and Ma and Xu (2011) corroborate our diagnosis.

For instance, in the study by Gweon et al. (2010), after the experimenter ostensively addressed the infant, she established joint referential attention, by removing the cloth covering the transparent box "and drew the child's attention to its contents by pointing to the window" (p. 9071), thereby making the statistical composition of the population of balls shared and relevant contextual background knowledge. In this communicative context, the infants could interpret the agent's subsequent communicative action–demonstrations as instances of either weak or selective sampling. In experiments 1–3, infants were therefore in a position to interpret the agent's action–demonstrations as instances of strong sampling. By contrast, in experiment 4, which tested the infants' sensitivity to random sampling, the agent first ostensively called the infants' attention to the fact that the sampling method she applied to draw the balls was random (i.e. in violation of the assumption of strong sampling): "rather than pulling the balls out, the experimenter shook the box upside down to let the balls fall out. Then she told the child, 'The next one is going to be yours'." (p. 9071).

The same is true of the procedure applied in the study by Ma and Xu (2011) where before sampling the six boring objects in each condition, the experimenter "first brought out a jar and directed children's attention to the objects inside (e.g. 'Look! I have a big jar. There are two kinds of things in it [Boring 13% condition]/there is only one kind of things in it [Boring 100% condition]. I am going to get some!')" (p. 405). In fact, following the sampling demonstrations (and before the test phase), the experimenter communicatively addressed the infant *once again* to make sure that the relevant contextual information about the population distribution from which the sampling evidence had been drawn was shared knowledge: "At the end of the sampling event, she directed children's attention to both the population and the sample, "Look! This many (holding the jar), and I got six of this one (holding the display container)" (p. 405). Furthermore, given the fact that the statistical evidence presented by the preferential sampling demonstrations in the study by Ma and Xu (2011) were preceded by strong ostensive–communicative cues directed to the toddlers, it seems entirely possible that what their results demonstrate is not merely that toddlers learnt to ascribe to others preferences different from their own on the basis of one individual's strong sampling behavior but that they would even be willing to generalize the other's preference to different agents as well (as is the case in study by Egyed et al., 2012).

5. CONCLUDING REMARKS

As the evidence reviewed in Section 2 shows, preverbal human infants are surprisingly able to represent the subjective motivations and the episodic contents of the epistemic states of agents of instrumental actions from a third-person perspective, in accordance with the principle of practical rationality. As the evidence reviewed in Sections 3 and 4 shows, their unique sensitivity to coded ostensive signals makes preverbal human infants surprisingly able to detect the presence of agents' communicative intentions and to interpret nonverbal communicative actions from a second-person perspective.

In Sections 3.2 and 3.3, we argued that in order to solve the puzzle of imitative learning, it is necessary to give up the rational imitation model according to which the model's action is construed as an instrumental action performed in accordance with the principle of practical rationality. Instead, the model's action should be construed as a communicative action whose goal is to teach new and relevant knowledge performed in accordance with the principle of relevance. This finding illustrates the separation between the system underlying infants' early reasoning about the psychological states of instrumental agents and the system whereby they acquire novel and relevant knowledge from communicative demonstrations when addressed by ostensive signals.

In Section 3.1, we reviewed evidence showing that in the context of joint actions where both agents have shared goals and share relevant common knowledge about a restricted set of familiar objects, preverbal human infants are able to disambiguate the intended referents of the nonverbal deictic pointing actions of their communicative partners. By contrast, in Section 4.1, we reviewed evidence showing that preverbal human infants are also prone to acquire deferential (trust based) beliefs about properties of artifact kinds from their interpretation of some of the referential actions and demonstrative displays of nonverbal communicative agents. In Section 4.2, we argued that such deferential beliefs about artifact kinds are formed in accordance with the principle of psychological essentialism. One crucial issue for further research is to investigate in detail what makes infants switch their expectation of relevance from episodic to nonepisodic information and conversely. In Section 4.3, we examined a selective sample of investigations about the ability of young children to make use of statistical inferences and we have argued that these studies are consistent with the idea that infants interpret strong sampling as part of a communicative action. Further work is needed to better understand how natural pedagogy and statistically based inductive learning combine in early infancy.

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