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Attribution of beliefs by 13-month-old infants

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ABSTRACT

In two experiments, we investigated whether 13-month-old infants expect agents to behave in a way consistent with information to which they have been exposed. Infants watched animations in which an animal was either provided information or prevented from gathering information about the actual location of an object. The animal then searched successfully or failed to retrieve it. Infants' looking times suggest that they expected searches to be effective when—and only when—the agent had had access to the relevant information. This result supports the view that infants' possess an incipient metarepresentational ability that permits them to attribute beliefs to agents. We discuss the viability of more conservative explanations and the relationship between this early ability and later forms of 'theory of mind' that appear only after children have become experienced verbal communicators.

Introduction

Current accounts of the conceptual competence underlying infants' understanding of agents have emphasized their ability to represent the goal of an action (Csibra & Gergely, 2003) as well as agents' internal source of energy (Leslie, 1994; Luo & Baillargeon, 2005). By their first birthday, infants distinguish agents from inanimate objects (Leslie, 1994; Mandler, 2004), interpret behaviors as goal-directed (Baldwin & Baird, 2001; Carpenter, Akhtar, & Tomasello, 1998; Gergely, Nádasdy, Csibra, & Bíró, 1995; Meltzoff, 1995; Woodward, 1998; Woodward & Sommerville, 2000), and attribute perceptual and attentional expectations to agents (Johnson, Slaughter, & Carey, 1998; Kuhlmeier, Wynn, & Bloom, 2003; Sodian, Schoeppner, & Metz, 2004; Schlottmann & Surian, 1999; Tomasello & Haberl, 2003).However, although most researchers now would probably endorse the view that infants have developed a teleological reasoning by 12 months, the degree to which they are also capable of attributing mental state content to agents remains a matter of controversy.

A mentalistic understanding of agents, or 'theory of mind', crucially involves the ability to interpret and predict their actions as a function of the content of their desires and beliefs. In their meta-analysis of 197 studies on false belief understanding, Wellman, Cross, and Watson (2001) proposed that this ability is absent in children before 4 years of age. However, while standard false beliefs tasks are typically failed by 3-year-olds, these failures are not enough to establish that younger children wholly lack metarepresentations. Toddlers at 2.7 years of age adjust their communicative behavior by taking into account whether their interlocutors have witnessed where an object has been hidden (O'Neill, 1996). Other evidence suggests that 3-year-olds have an implicit understanding of mental states (Clements & Perner, 1994; Garnham & Ruffman, 2001) or an understanding in which they have low confidence (Ruffman, Garnham, Import & Connoly, 2001). There are also reports of successful performance at 3 years of age when pragmatically more explicit test questions are used instead of standard ones (e.g., Siegal & Beattie, 1991; Surian & Leslie, 1999; Yadzi, German, Defeyter & Siegal, 2006).

Can infants in their second year represent epistemic mental states such as beliefs? Only one published study has so far yielded a positive answer to this question. Onishi and Baillargeon (2005) tested 15-month-olds in a violation of expectations paradigm and infants' looking behavior turned out to be just what one would predict if they expected an actor's behavior to be guided by her true or false belief about a toy's hiding place. Infants looked longer at search in the wrong place performed by a person who knew where the object was and they looked longer at search in the right place performed by a person holding a false belief about the object location, suggesting that, even at the age of 15 months, infants can represent beliefs.

However, this interpretation has not gone unchallenged (Perner & Ruffman, 2005), and what is at stake here is not only a remarkable revision of the developmental time course of mindreading skills, but also the role of different developmental mechanisms that have been proposed to be responsible for this fundamental aspect of human cognition. The presence of metarepresentations at such an early age is more coherent with core knowledge views of mindreading that stress the role of highly canalized universal predispositions (Frith & Frith, 1999; Leslie, 1987), than with alternative models that emphasize the role of theory revision and cross-cultural variations (Gopnik & Meltzoff, 1997; Lillard, 1998).

Thus the main aim of our investigation was to test whether infants' expectations about an agent's future actions towards an object take into account the agent's previous exposure to relevant information about the object's location.

Experiment 1

Following a paradigm introduced by Woodward (1998), babies were first familiarized with four search actions. Each time, an agent looked at two opaque screens while a hand put an apple behind one of them and a piece of cheese behind the other one. The agent then went each time behind the same screen to chew on the same object. In the test trials, the objects were placed in reversed positions before the agent entered the scene. The agent then either searched behind the same screen as before or behind the other one. In one condition, the screens during the test trials were very low leaving the objects in full view; in the other condition, the screens hid the objects from the agent's view as in the familiarization phase. If infants expect the agent to go where there had been evidence of the preferred object's location, then their looking times for searching should differ in the two conditions: they should expect successful actions only when the agent is correctly informed about the objects' actual positions.

Method

Participants. Participants were 56 full-term infants, 24 females and 32 males (12 months 2 days to 14 months 5 days, M = 13 months 4 days). Another 8 infants were excluded due to fussiness. Infants were recruited by their birth records, from the birth register of the Padua, Italy, City Hall, and contacting their parents by telephone. Parents were not compensated for their participation, but they were given a certificate of attendance.

Apparatus and stimuli. Infants sat on their mothers' lap facing a 19" computer monitor placed at eye level at about 60 cm from their head. Parents were instructed to be silent and avoid any interference with their babies. A black cardboard was placed around the monitor and a curtain was hung at the back of the monitor to conceal distracting stimuli. The room was dimly lit. The entire session was videotaped using two video cameras, one focused on the infant's face and the other one focused on the computer monitor. A Macintosh computer was used to control the computer-animated movies. The stimuli staged a green caterpillar (4 x 1.5 cm), a red apple (2.7 x 1.9 cm), a yellow piece of cheese (4 x 2.3 cm), two blue screens (10.5 x 3.8 cm) and an arm (7.7 x 1.7 cm). The velocity of the caterpillar and the arm were about 4 and 8 cm/s, respectively. Each event started with the stage showing the two screens only and finished with a red curtain that was lowered on the stage.

Design and procedure. Equal numbers of infants were randomly assigned to one of two conditions. Both conditions involved five familiarization trials, followed by one test trial. At the beginning of each trial, infants' attention was drawn to the monitor by squeezing a noisy toy. When infants looked at the monitor, one experimenter started the animation program and the video recording equipment, while another experimenter, who was blind to the condition and type of test event, timed infants' looking times as the caterpillar reached the goal. Each trial ended when infants looked away for more than 2 consecutive seconds or until 120 s elapsed. Sessions were videotaped and later coded independently by two experimenters. Interjudge reliability, based on 43% of the tapes that were coded by a second coder, was high (mean Pearson's r = .99). Two experimenters re-examined the tapes and found that infants had looked at 93 % of the critical object hiding events.

In the *seeing condition*, the testing session started with four familiarization trials involving a caterpillar moving into the central area of the computer monitor and stopping in front of two opaque screens (see Fig. 1). Then a hand put an apple behind one screen and a piece of cheese behind the other one. The caterpillar then went each time behind the same screen to chew on the same object hidden from his view, but with the top visible from the point of view of the spectator who was ideally situated well above and behind the caterpillar. On the fifth trial, screens were replaced with very short barriers, leaving the objects always fully visible, and the hand placed the objects in the opposite locations with respect to previous trials. The agent never entered the scene. Then children

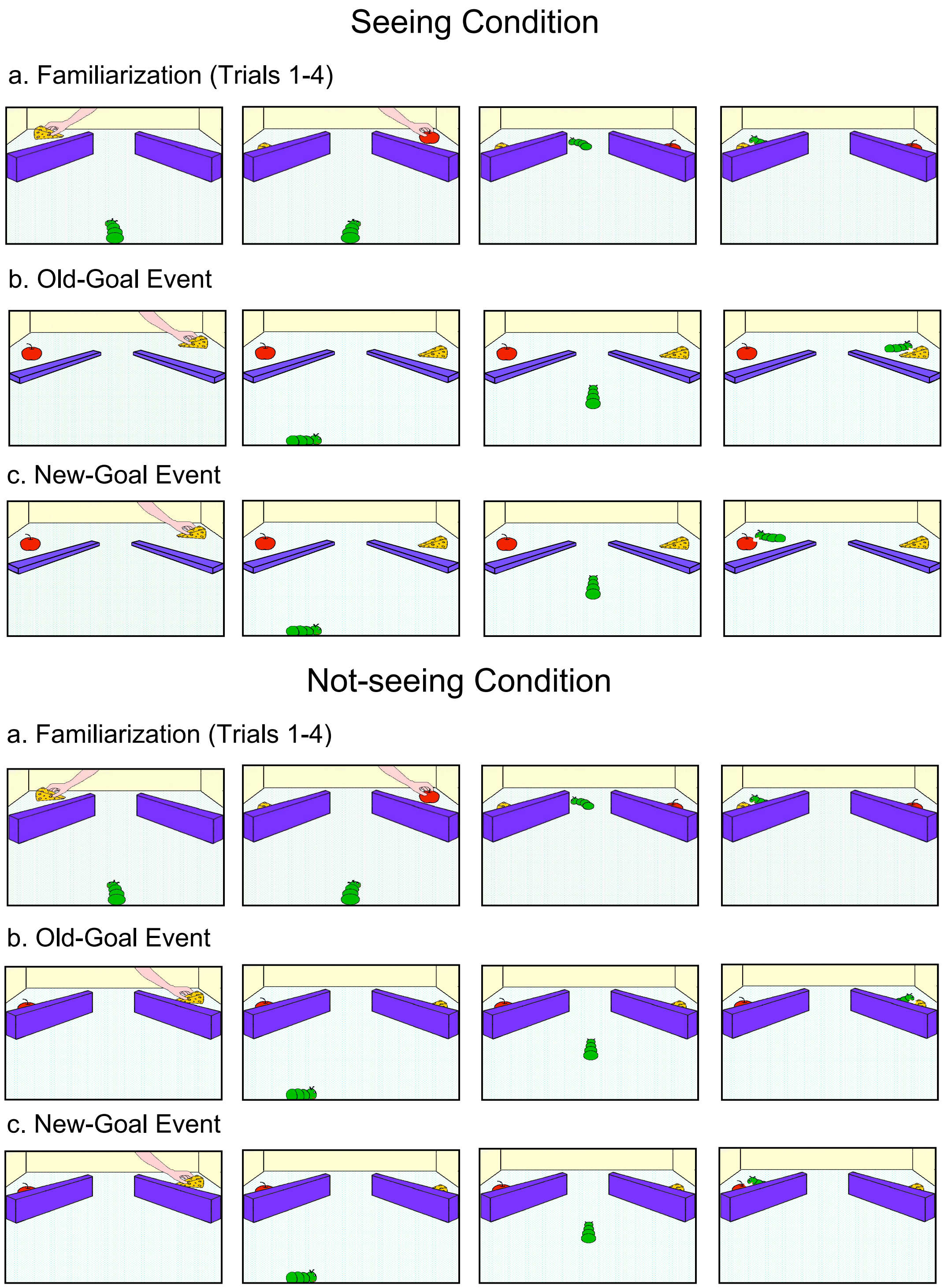

Figure 1*. Illustration of the stimuli presented in the seeing and not-seeing conditions in Experiment 1. Both conditions began with four identical familiarization trials (a), during which a caterpillar looked at a hand placing two different objects behind two opaque screens and then went to reach and bite one of the two objects. On the fifth familiarization trials (not shown on the figure), the objects were placed on opposite locations and the agent never appeared. One test trial followed during which objects were placed as in the fifth familiarization trial. In the old-goal events (b) the agent went to reach the same object chosen in the familiarization trials, while in the new-goal events (c) the agent went to reach the other one. In the not-seeing condition test trials, tall screens obstructing the agent's view were used, whereas in the seeing condition test trials low screens that left the objects fully visible were used.*

in the seeing condition received a single test trial with short barriers and the agent entering right after the objects had been placed in their new locations.

In the *not-seeing condition,* the structure of the event was identical to that of the seeing condition, but on all trials the barriers were always tall enough to prevent the caterpillar from seeing what was behind them. The positions of the objects and the object-goal in the familiarization and test trials were counterbalanced across participants. In each condition, 14 infants saw the caterpillar moving along a new path and reaching the same object chosen during the familiarization trials (old-goal event), whereas the other 14 infants saw the agent reaching the alternative object following the old path (new-goal event).

Results

Looking times in the first four *familiarization trials* were analyzed in a 2 X 2 X 2 X 4 analysis of variance (ANOVA) with condition (seeing or not-seeing), object goal (apple or cheese), and order of object placement (apple first or cheese first) as between-subjects variables and trial (first, second, third or fourth) as within-subjects variable. The only significant effect was due to the object goal variable (M_{cheese} = 18.2 s, SD = 9.6; M_{apple} = 12.9 s, SD = 9.6), $F(1,48) = 4.36$, $p < .05$ (η_p^2 = .083 , p_{rep} = .89). Although the trial effect was not significant, a planned comparison between the first and the forth familiarization trials showed a significant decrease in looking times ($M_{trial\ 1}$ = 18.5 s, SD = 16.5; $M_{trial\ 4}$ = 14.3 s, SD = 13.8), $t(55) = 1.74$, $p < .05$, one-tail. Looking times in the fifth familiarization trials did not differ significantly in the two conditions.

The infants' looking times during the *test trials* were entered into a 2 X 2 ANOVA with condition (seeing or not-seeing) and event (new- or old-goal) as between-subjects factors. The only significant effect was due to the Condition X Event interaction, $F(1,52) = 5.69$, $p < .025$ (η_p^2 = .099, p_{rep} = .93). In the seeing condition infants looked longer at new-goal events than at old-goal events ($M_{new\text{-}goal}$ = 32.71 s, SD = 38.85; $M_{old\text{-}goal}$ = 10.66 s, SD = 6.38), whereas they did the opposite in the not-seeing condition ($M_{new\text{-}goal}$ = 10.56 s, SD = 7.56; $M_{old\text{-}goal}$ = 14.48 s, SD = 7.37; see Fig. 2). The very high variability found in new-goal test trials in the seeing condition is mostly due to two subjects that reached the limit of looking time admitted in our procedure. After excluding these two responses, the pattern of results appears more homogeneous ($M_{new\text{-}goal}$ = 18 s, SD = 13.56 s), but it does not differ meaningfully from the previous one and a further ANOVA revealed, again, a significant Condition X Event interaction, $F(1, 50) = 5.56$, $p < .025$ (η_p^2 = .100). Two separate t-tests performed on each condition showed a statistically reliable difference in the seeing condition, $t(26) = 2.10$, $p < .05$, two-tailed (p_{rep} = .88), but not in the not-seeing condition, $t(26) = 1.39$, $p > .05$ (p_{rep} = .745).

The results indicate that infants took into account the difference in the agents' viewing conditions. Given that, on the test trials, the objects were visible to the infants in both conditions, but were visible also to the agent in the seeing condition only, these results indicate that infants are capable of distinguishing between their own visual perspective and that of others. This confirms earlier findings showing that 14-month-olds understand that screens may prevent another person's perception even when they do not obstruct their own view (Caron, Kiel, Dayton & Butler, 2002).

Taking into account the agents' viewing conditions apparently lead infants to generate different expectations regarding the agents' future actions in the two conditions. The fact that there was a significant difference for the old- *vs*. new-goal events only in the seeing condition suggests that infants expected a successful action in that condition, whereas they did not have any specific expectation in the not-seeing condition. This would be consistent with the attribution of ignorance to the agent, rather than false belief, in the not-seeing condition.

Although the reported effects can be seen as evidence of mindreading, it is also possible to propose that infants applied an *ad-hoc* heuristic that links perception to successful action. This simple rule would predict successful actions only for agents that are perceptually connected to their goals (Flavell, 1988). Another possible explanation is that infants in the not-seeing condition were unsure whether or not the caterpillar could detect the objects behind the screens and thus were unsure of where the caterpillar should go. Finally, it is possible that, in the test trials of the not-seeing condition, the infants could not discern the two objects and thus they were also confused about where the caterpillar would go. Experiment 2 presents a stringent test of knowledge attribution designed to rule out these alternatives.

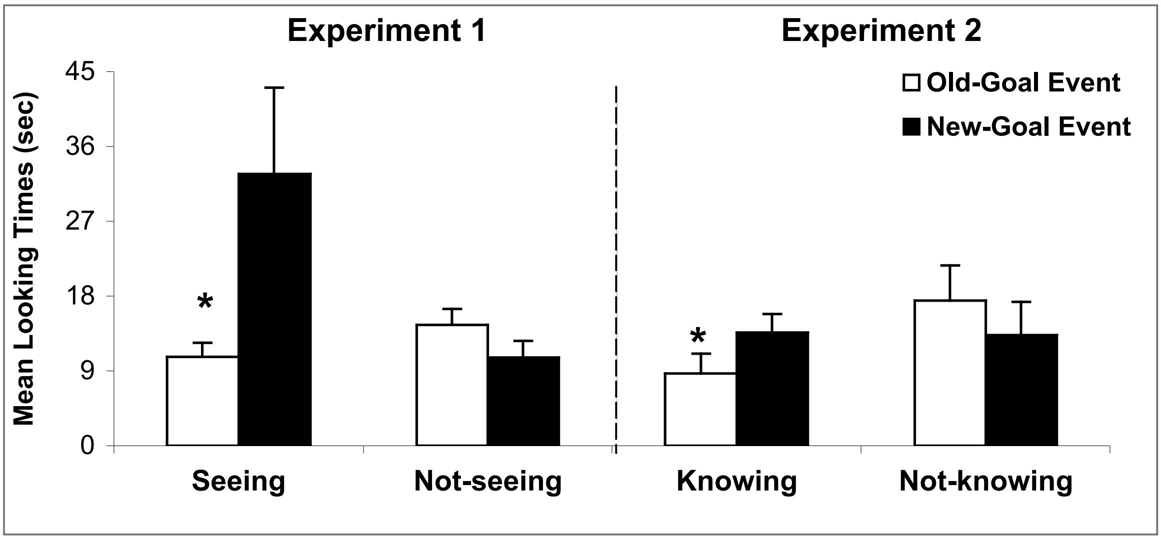

Figure 2. *Results of Experiments 1 and 2: mean looking times (with standard errors) at the new- and old-goal test events as a function of condition. An asterisk denotes a statistically reliable difference.*

Experiment 2

In Experiment 1, infants formed different behavioral expectations for agents that can or cannot perceive an object-goal. In the test trials of Experiment 2, infants were exposed to agents who were always perceptually disconnected from the goals because tall screens hid the objects from them in both conditions. However, the agent was present when objects were placed behind the screens in one condition, and was absent in the other condition. In the first condition, where perceptual information about the location of the goal-object had been available to the agent right before the time of action, would infants expect the agent to be guided by this information? This would suggest that infants are capable of attributing true beliefs (or knowledge) to agents. In the second condition, where perceptual information about the location of the goal-object was not available to the agent at the time of action nor had been available right before, would infant lack specific expectations about the agent's action? This would suggest that they are just able to form different expectations regarding agents with true beliefs, and agents without true beliefs (whether in the form of ignorance or of false beliefs). Or else, would infants expect the agent's behavior to be guided by now obsolete information that had been provided by past observations (during the familiarization trials) of the goal-object? This would suggest that infants are able to form different expectations regarding agents with true beliefs and agents with false beliefs.

Method

Participants. Participants were 54 full-term infants, 26 females and 28 males (12 months 3 days to 14 months 2 days, M = 13 months 3 days). Another 7 infants were eliminated due to fussiness. Subjects were recruited as in Experiment 1. No infant participated to both experiments.

Apparatus, procedure and stimuli. The experimental apparatus and procedure were like in Experiment 1. There were two conditions: knowing and not-knowing. Tall screens were used for all trials in both conditions. The not-knowing condition was wholly identical to the not-seeing condition of Experiment 1. Note that, in the test trials in this condition, agents arrived on stage after the objects had been placed behind the screens. The knowing condition test trials were like the test trials in not-knowing condition on all respects except one: in the knowing condition test trials the agent arrived on stage before the objects had been placed behind the screens and looked at the objects' placement. Twenty-eight infants participated in the knowing condition and 26 in the other condition. Half of the participants in each condition were tested on new-goal events and the other half were tested on old-goal events. Two coders examined all the videotapes and coded infants' looking times independently; one of them was blind to the experimental condition and the type of test events. The interjudge reliability was high (mean Pearson r = .99). Two experimenters re-examined the tapes and found that infants watched 94 % of the object hiding events.

Results

In the first four *familiarization trials,* preliminary analyses found no effects of object position and object goal on infants' looking times. A 2 X 4 ANOVA was performed on these trials with condition (knowing or not-knowing) as between-subjects variable and trial order (1 to 4) as within-subjects variable. This analysis yielded no significant main effect or interaction. A t-test on looking times in the fifth familiarization trial showed no significant difference in the two conditions.

Looking times in the *test trials* were entered into a 2 X 2 ANOVA with condition (knowing or not-knowing) and event (new-goal or old-goal) as between-subjects factors, after excluding 5 outliers who showed looking times 2 SD above the mean. This analysis revealed a significant Condition X Event interaction, $F(1,45) = 6.5$, $p < .015$ ($\eta_p^2 = .127$, $p_{rep} = .94$) (Fig. 2). In the knowing condition, infants looked longer at the new-goal events ($M_{new\text{-}goal} = 13.6$ s; $SD = 8.7$; $M_{old\text{-}goal} = 8.7$ s; $SD = 8.7$; $t(24) = 2.2$, $p < .034$, $p_{rep} = .90$), whereas, in the not-knowing condition, they looked longer at the old-goal events ($M_{old\text{-}goal}$: 17.5 s, $SD = 16.0$; $M_{new\text{-}goal} = 13.3$ s, $SD = 13.7$), but the difference was not statistically reliable, $t(21) = 1.7$. However, the difference was reliable when the responses of the not-knowing condition were combined with those of the identical condition in Experiment 1 ($M_{new\text{-}goal} = 11.8$ s; $SD = 10.7$; $M_{old\text{-}goal} = 16.0$ s; $SD = 12.3$) and three outliers whose responses were more than two SDs above the mean were excluded, $t(49) = 2.1$, $p < .05$, two-tailed, $p_{rep} = .919$).

Infants appear to generate correct expectations about the agent's action when the relevant information, although no more perceptually available, had been available to the agent right before, suggesting that infants are capable of attributing true beliefs to agents. Taken on their own, the results of this second experiment might suggest that infants have no specific expectations about the agent's action when relevant information is not perceptually available to the agent and had not been available right before. However, the combined results of Experiments 1 and 2 suggest rather that, in such a situation, infants expect the agent behavior to be guided by now obsolete information, in other words, it appears that infants are able to distinguish agents with true or with false beliefs.

General Discussion

Expecting information to guide an agent's choices even though it is no more accessible through perception is, of course, the hallmark of a mentalistic understanding of actions. The results of our investigation thus provide evidence of an early form of mindreading ability—in the specific sense of sensitivity to mental contents. This ability was tested on events involving a non-human agent, suggesting that infants do apply such ability not only to humans, but possibly to all entities recognized as agents.

Our findings converge with those of Onishi and Baillargeon (2005) on 15-month-olds infants' expectations about human actions and suggest that 13-month-olds in our study form correct expectations based on the fact that the agent' behavior is guided by true beliefs. Moreover, combining the results of the not-seeing condition of Experiment 1 and the not-knowing condition of

Experiment 2 (which were identical in every respect) provides evidence, which of course should be further confirmed, that these infants were able to discriminate behavior based on true beliefs from behavior based on false beliefs.

Our design rules out alternative explanations that had been proposed for Onishi and Baillargeon's results. These results are at odds with Wellman et al.'s (2001) account of theory of mind development and so it is appropriate to ask whether they could be explained, more conservatively, without assuming any mindreading ability. Perner and Ruffman (2005) proposed that Onishi and Baillargeon's results could be due to infants' ability to form three-way agent-object-place associations by paying attention to where the agents last looked before searching for the object. However, the results of our studies challenge the viability of this alternative explanation. First, infants were presented with two objects and two relevant locations, and their behavior cannot be explained solely by their having formed a three-way agent-object-place association. Moreover, because the order in which the two objects were placed behind the screens was counterbalanced, infants' behavior cannot be due to a putative expectation that agents will act towards the object that they last saw.

Perner and Ruffman suggested another, less easily testable, alternative explanation based on *ad-hoc* heuristics. They claim that "infants may have noticed (or are innately predisposed to assume) that people look for an object where they last saw it and not necessarily where the object actually is." (p. 215). Such regularity, however, is not something that one could easily "notice" (as opposed to infer from knowledge of people's psychology), since evidence of where people last saw an object is not easily tracked in everyday experience. By contrast, what one commonly observes is people picking an object in plain sight, or looking in several places for an object the location of which they have forgotten. The relevant evidence that a 13-month-old might have gathered to acquire the *ad-hoc* rule and the ability to use such evidence are unlikely to be sufficient. As for the suggestion that there might be an innate predisposition to assume that people look for an object where they last saw it, it looks like a case of jumping into the river of *ad-hoc* nativist stories to avoid being wetted by the more principled hypothesis that the mindreading ability humans demonstrate at 4 years is based on a strong biological predisposition of which there is a manifestation in infants' rudimentary ability of attributing mental contents to agents. A more plausible and parsimonious explanation is that incipient mindreading ability is present much earlier than was hitherto generally assumed. This conclusion is also consistent with evidence from recent studies using non-verbal versions of ToM tasks (Scott & Baillargeon, 2006; Song, 2006).

The infants we have studied take into account information that had been perceptually available to the agent only prior to its action and expect it to be still guiding its actions. Information that cannot be perceptually accessed but that is nevertheless available to agents is, paradigmatically, mental content. We propose that infants who expect agents' behavior to be guided by such internally available information thereby exhibit an ability to attribute mental content, and this is mindreading proper, however rudimentary. This does not imply, of course, that infants are also able to deploy conscious metacognitive inferences or to articulate a conception of beliefs as truth-evaluable mental states. Numerous results on preschoolers' theory of mind indicate that these higher capacities are not present before four years of age (Wellman *et al*., 2001). What Onishi and Baillargeon's and our results do imply is that the richer mindreading abilities demonstrated by children on verbal tasks are likely develop from a more rudimentary, incipient metarepresentational competence found in infants.

This conclusion has, in turn, important implications for the issue of how language acquisition affects theory of mind development. Evidence on typically developing (de Villiers & Pyers, 2002; Lohmann & Tomasello, 2003) and deaf children (Peterson & Siegal, 2000; Siegal & Peterson, in press) shows that language competence and conversational experience are important predictors of success on traditional theory of mind tasks. Less clear is how such effects are obtained and what are the mechanisms responsible for the correlations reported in the literature (Harris, 2005). The early competence revealed by the present results and those reported by Onishi and Baillargeon (2005) implies that, while linguistic and conversational experience in infancy and early childhood may play a role in the transition from rudimentary to more elaborate forms of mindreading, it is unlikely to provide the conceptual foundations of children's metarepresentational ability. This conclusion dovetails with the view, argued by Sperber and Wilson (2002) that verbal communication could not have emerged phylogenetically and cannot properly develop ontogenetically without the presence of mindreading skills in infancy.

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