Research Article

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 that is 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 the object. 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 relation between this early ability and later forms of theory of mind that appear only after children have become experienced verbal communicators.***

Current accounts of the conceptual competence underlying infants' understanding of agents have emphasized infants' ability to represent the goal of an action (Gergely & Csibra, 2003), as well as agents' internal source of energy (Leslie, 1994; Luo & Baillargeon, 2005). By their first birthday, infants distinguish agents from inanimate objects (Mandler, 2004), interpret behaviors as goal directed (Baldwin & Baird, 2001; Gergely, Nádasdy, Csibra, & Bíró, 1995; Meltzoff, 1995; Woodward, 1998; Woodward & Sommerville, 2000), and attribute perceptual, attentional, and dispositional properties to agents (Johnson, Slaughter, & Carey, 1998; Kuhlmeier, Wynn, & Bloom, 2003; Schlottmann & Surian, 1999; Sodian, Schoeppner, & Metz, 2004; Tomasello & Haberl, 2003). However, although most researchers now would probably endorse the view that infants have developed teleological reasoning by the age of 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 a 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, although standard false-belief 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 of mental states in which they have low confidence (Ruffman, Garnham, Import, & Connoly, 2001). There are also reports of successful performance on false-belief tasks 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; Yazdi, German, Defeyter, & Siegal, 2006).

Can infants in their second year represent epistemic mental states such as beliefs? Thus far, only one published study has 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 his or her true or false belief about a toy's hiding place. Infants looked longer at search in the wrong place when it was performed by a person who knew where the object was rather than by a person who did not know where the object was, and they looked longer at search in the right place when it was performed by a person holding a false belief about the object's location rather than by a person holding a true belief about the object's location. These results suggest that, even at the age of 15 months, infants can represent beliefs.

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However, this interpretation has not gone unchallenged (Perner & Ruffman, 2005), and what is at stake here is a remarkable revision not only of the developmental time course of mind-reading skills, but also of 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 mind reading that emphasize the role of highly canalized universal predispositions (Baron-Cohen, 1995; 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 toward 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), we first familiarized babies 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. The apple was always placed behind the same screen, as was the cheese. The agent then went behind the same screen each time 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 searched either behind the same screen as before or behind the other screen. 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 the infants expected the agent to search where the evidence indicated the preferred object would be, then their looking times for searching would differ in the two conditions: They would expect successful search only when the agent had been correctly informed about the objects' actual positions.

Method

Subjects

Subjects 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 because of fussiness. Infants were recruited by searching 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

Each infant sat on his or her mother's lap, facing a 19-in. computer monitor placed at eye level about 60 cm from the infant's head. 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 focused on the computer monitor. A Macintosh computer was used to control the computer-animated movies. The stimuli appearing on the stage in the movies were a green caterpillar (4 × 1.5 cm), a red apple (2.7 × 1.9 cm), a yellow piece of cheese (4 × 2.3 cm), two blue screens (10.5 × 3.8 cm), and an arm (7.7 × 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 the two conditions. Both conditions involved five familiarization trials, followed by one test trial. At the beginning of each trial, the infant's attention was drawn to the monitor by squeezing a noisy toy. When the infant 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 (see later in this section), timed the infant's looking time as the caterpillar reached the goal object. Each trial ended when the infant looked away for more than 2 consecutive seconds or 120 s elapsed, whichever came first. Sessions were videotaped and total looking time was later coded independently by two experimenters. Interjudge reliability, based on the 43% of the tapes that were coded by a second coder, was high (mean Pearson's $r = .99$). Two experimenters reexamined the tapes to check how often the infants had watched the hand placing the two objects behind the screens. The infants had looked at almost all (93%) 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). Next, a hand put an apple behind one screen and a piece of cheese behind the other. The locations of the apple and cheese did not vary. On each trial, the caterpillar then went behind the same screen to chew on the same object, which was hidden from its view; the top of the object, however, was visible from the point of view of the spectator, who was ideally situated well above and behind the caterpillar. On the fifth familiarization trial, the screens were replaced with very short barriers, leaving the objects always fully visible, and the hand placed the objects in the locations opposite where they had been placed in the previous trials. The agent never entered the scene. Finally, on the single test trial, the short barriers were in place, and the agent entered immediately after the objects had been put in their new locations.

The trials in the *not-seeing condition* were identical to those in the seeing condition, except that the barriers were always tall enough to prevent the caterpillar from seeing what was behind them.

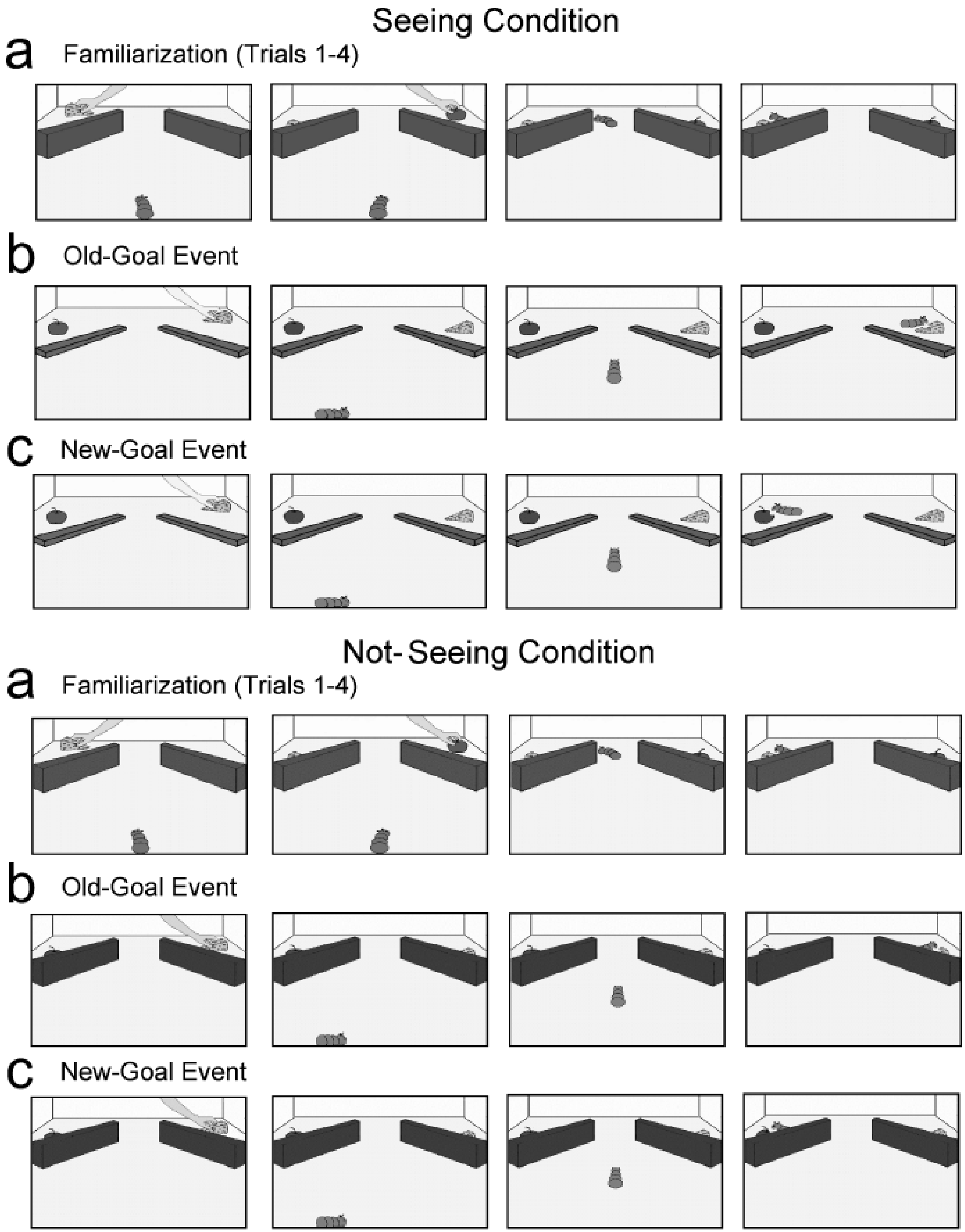

Fig. 1. Illustration of the stimuli presented in the seeing and not-seeing conditions of Experiment 1. Both conditions began with four identical familiarization trials (a), during which a caterpillar looked at a hand placing two different objects behind two opaque screens and then went to reach and bite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

The positions of the two objects, the order in which the two objects were placed behind the screens, and the goal object in the familiarization and test trials were counterbalanced across subjects. In the test trials of each condition, 14 infants saw the caterpillar move along a new path and reach the same object chosen during the familiarization trials (old-goal event), whereas the other 14 infants saw the agent reach the alternative object by following the old path (new-goal event).

Mothers were instructed to be silent and avoid any interference with their babies during the experiment.

Results

Looking times in the first four familiarization trials were analyzed in a 2 × 2 × 2 × 4 analysis of variance (ANOVA) with condition (seeing or not seeing), goal object (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 a within-subjects variable. Only the goal-object variable had a significant effect (cheese: $M = 18.2$ s, $SD = 9.6$; apple: $M = 12.9$ s, $SD = 9.6$), $F(1, 48) = 4.36$, $p < .05$, $\eta_p^2 = .083$, $p_{rep} = .89$. Although the effect of trial was not significant, a planned comparison between the first and the fourth familiarization trials showed a significant decrease in looking times (Trial 1: $M = 18.5$ s, $SD = 16.5$; Trial 4: $M = 14.3$ s, $SD = 13.8$), $t(55) = 1.74$, $p < .05$ (one-tailed). Looking time in the fifth familiarization trial did not differ significantly between the two conditions.

The infants' looking times during the test trials were entered into a 2 × 2 ANOVA with condition (seeing or not seeing) and event (new or old goal) as between-subjects factors. The only significant effect was the Condition × Event interaction, $F(1, 52) = 5.69$, $p < .025$, $\eta_p^2 = .099$, $p_{rep} = .93$. In the seeing condition, infants looked longer at new-goal events than at old-goal events (new goal: $M = 32.71$ s, $SD = 38.85$; old goal: $M = 10.66$ s, $SD = 6.38$), whereas in the not-seeing condition, the pattern was the opposite (new goal: $M = 10.56$ s, $SD = 7.56$; old goal: $M = 14.48$ s, $SD = 7.37$; see Fig. 2). The very high variability in new-goal test trials in the seeing condition was mostly due to 2 subjects who reached the maximum looking time allowed in our procedure. With the data from these 2 subjects excluded, the pattern of results appeared more homogeneous (new goal: $M = 18$ s, $SD = 13.56$ s), but infants' preference for new-goal events in the seeing condition and for old-goal events in the not-seeing condition did not change meaningfully. An ANOVA revealed, again, a significant Condition × Event interaction, $F(1, 50) = 5.56$, $p < .025$, $\eta_p^2 = .10$, and separate t tests for the two conditions showed a statistically reliable difference between the old-goal and new-goal events 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 in both conditions took into account the agents' visual perspective. 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 other individuals. This confirms earlier findings showing that 14-month-olds understand that screens may prevent another person from perceiving something even when the screens do not obstruct the infants' own view of that object (Caron, Kiel, Dayton, & Butler, 2002).

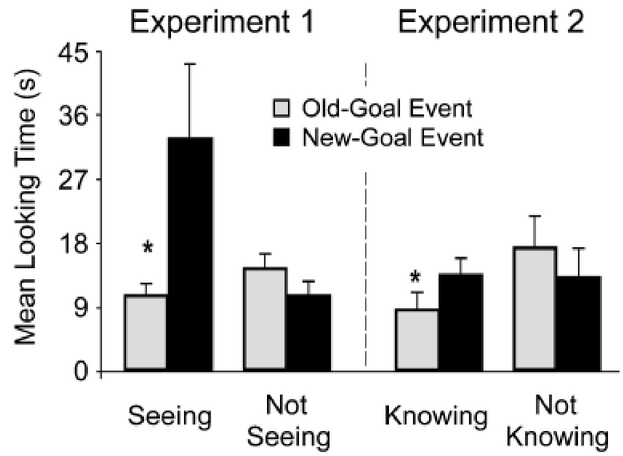

Fig. 2. Results of Experiments 1 and 2: mean looking time at the new- and old-goal test events as a function of condition. An asterisk denotes a statistically reliable difference between the two events. Error bars indicate standard errors.

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

Although the reported effects can be seen as evidence of mind reading, it is also possible to account for the results by proposing that the infants applied an ad hoc heuristic linking 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 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 were also confused about where the caterpillar should go. Experiment 2 was a stringent test of knowledge attribution designed to rule out these alternative explanations.

EXPERIMENT 2

In Experiment 1, infants formed different behavioral expectations depending on whether an agent could or could not perceive a goal object. In the test trials of Experiment 2, all infants were exposed to an agent who was perceptually disconnected from the goal object because tall screens hid the objects from them.

However, the agent was present when objects were placed behind the screens in one condition, and the agent was absent when the objects were placed in the other condition. In the former condition, in which perceptual information about the location of the goal object was available to the agent right before the time of action, would infants expect the agent to be guided by this information? If so, this would suggest that infants are capable of attributing true beliefs (or knowledge) to agents. In the latter condition, in which perceptual information about the location of the goal object was not available to the agent either at or right before the time of action, would infants lack specific expectations about the agent's action? If so, the results of the two conditions combined would suggest that infants are 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 would infants expect the agent's behavior to be guided by obsolete information that had been provided by past observations (during the familiarization trials) of the goal object? If so, this would suggest that infants are able to form correct action predictions regarding agents that hold a false belief.

Method

Subjects

The subjects 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 excluded because of fussiness. Subjects were recruited as in Experiment 1. No infant participated in both experiments.

Apparatus, Procedure, and Stimuli

The experimental apparatus and procedure were the same as in Experiment 1, with the following exceptions. There were two conditions: knowing and not knowing. Tall screens were used for all trials in both conditions. The not-knowing condition was completely identical to the not-seeing condition of Experiment 1. Note that in the test trials in this condition, the agent arrived on the stage after the objects had been placed behind the screens. The test trials in the knowing condition were like the test trials in the not-knowing condition in all respects except one: In the knowing condition, the agent arrived on the stage before the objects were placed behind the screens and looked at the objects' placement. Twenty-eight infants participated in the knowing condition, and 26 participated in the not-knowing condition. Half of the subjects 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 the coders was blind to the experimental condition and the type of test event. The interjudge reliability was high (mean Pearson's $r = .99$). Two experimenters reexamined the tapes and found that infants watched 94% of the object-hiding events.

Results

Preliminary analyses of the first four familiarization trials found no effects of order of object placement or goal object on infants' looking times. A 2×4 ANOVA, with condition (knowing or not knowing) as a between-subjects variable and trial (first, second, third, or fourth) as a within-subjects variable, yielded no significant main effects or interaction for these trials. A t test on looking times in the fifth familiarization trial showed no significant difference between the two conditions.

Looking times in the test trials were entered into a 2×2 ANOVA with condition (knowing or not knowing) and event (new goal or old goal) as between-subjects factors (5 outliers with looking times 2 standard deviations above the mean were excluded). This analysis revealed a significant Condition $\times$ 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 than at the old-goal events (new goal: $M = 13.6$ s, $SD = 8.7$; old goal: $M = 8.7$ s, $SD = 8.7$), $t(24) = 2.2, p < .034, p_{rep} = .90$, whereas in the not-knowing condition, infants showed a nonreliable trend to look longer at the old-goal events than at the new-goal events (old goal: $M = 17.5$ s, $SD = 16.0$; new goal: $M = 13.3$ s, $SD = 13.7$), $t(21) = 1.7$. When the responses in the not-knowing condition were combined with those of the identical condition in Experiment 1 and 3 outliers whose responses were more than two standard deviations above the mean were excluded, the difference between old-goal and new-goal events was reliable (new goal: $M = 11.8$ s, $SD = 10.7$; old goal: $M = 16.0$ s, $SD = 12.3$), $t(49) = 2.1, p < .05$ (two-tailed), $p_{rep} = .919$.

Infants appeared to generate correct expectations about the agent's action when the relevant information, although no longer perceptually available, had been available to the agent right before the action. This result suggests 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 an agent's action when relevant information is not perceptually available to the agent and had not been available right before the action. However, the combined results of Experiments 1 and 2 suggest that in such a situation, infants expect the agent's behavior to be guided by now-obsolete information; in other words, it appears that infants are able to distinguish agents with true beliefs from those with false beliefs.

GENERAL DISCUSSION

Expecting information to guide an agent's choices even though the information is no longer 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 mind-reading ability—in the specific sense of sensitivity to mental contents. This ability was tested in events involving a nonhuman agent, so the results suggest that infants may apply this ability to all entities recognized as agents, not only to humans.

Our findings converge with Onishi and Baillargeon's (2005) results regarding 15-month-old infants' expectations about human actions and suggest that the 13-month-olds in our study formed correct expectations that an agent's behavior would be guided by his or her 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 generate correct behavioral expectations also when the agent held a false belief.

Our design rules out alternative explanations that have been proposed for Onishi and Baillargeon's (2005) results. The results from the present study are at odds with the account of theory-of-mind development proposed by Wellman et al. (2001), so it is appropriate to ask whether they could be explained, more conservatively, without assuming any mind-reading 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 agents last looked before searching for the object. However, the results of our studies challenge the viability of this alternative explanation. First, the 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. Second, because the order in which the two objects were placed behind the screens was counterbalanced, the infants' behavior cannot have been due to a putative expectation that the agent would move toward the object that it last saw.

Perner and Ruffman (2005) suggested another, less easily testable, alternative explanation based on ad hoc heuristics. They claimed 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), because evidence of where people last saw an object is not easily tracked in everyday experience. By contrast, what one commonly observes is people reaching for an object in plain sight, or looking in several places for an object whose location they have forgotten. It is unlikely that a 13-month-old would have gathered sufficient relevant evidence to acquire this ad hoc rule. As for the suggestion that there might be an innate predisposition to assume that people look for an object where they last saw it, this appears to be a case of jumping into the river of ad hoc nativist stories in order to avoid being doused by the more principled nativist hypothesis that the mind-reading ability humans demonstrate at 4 years is based on a strong biological predisposition that is already manifest in infants' rudimentary ability to attribute mental contents to agents. The hypothesis that there is an early metarepresentational competence provides a more plausible and parsimonious explanation for the results reported here and for Onishi and Baillargeon's (2005) findings, and it is also consistent with evidence from recent studies using nonverbal versions of theory-of-mind tasks (Scott & Baillargeon, 2006; Song, 2006; Southgate, Senju, & Csibra, 2007, this issue).

The infants we studied took into account information that had been perceptually available to the agent only prior to its action and expected that information to still guide the agent's action. 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 mind reading proper, however rudimentary. We do not intend to imply 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 4 years of age (Wellman et al., 2001). What our results and those of Onishi and Baillargeon (2005) do imply is that the richer mind-reading abilities demonstrated by older children on verbal tasks likely develop from a more rudimentary, incipient metarepresentational competence found in infants.

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

Acknowledgments—This work was supported by the Italian Government Research Grant PRIN 2005 and fostered by the Annual Arts and Humanities Research Board Conferences on Innateness and the Structure of the Mind (Sheffield, United Kingdom). We thank Susan Carey, Michael Siegal, and two anonymous reviewers for their useful comments on earlier drafts of this article. We also thank the staff at the Dipartimento di Psicologia dello Sviluppo e della Socializzazione, University of Padua, and the participating parents and infants for their kind help.

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(RECEIVED 7/25/06; REVISION ACCEPTED 9/27/06;
FINAL MATERIALS RECEIVED 10/25/06)