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Research Article

Action Anticipation Through Attribution of False Belief by 2-Year-Olds

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ABSTRACT—***Two-year-olds engage in many behaviors that ostensibly require the attribution of mental states to other individuals. Yet the overwhelming consensus has been that children of this age are unable to attribute false beliefs. In the current study, we used an eyetracker to record infants' looking behavior while they watched actions on a computer monitor. Our data demonstrate that 25-month-old infants correctly anticipate an actor's actions when these actions can be predicted only by attributing a false belief to the actor.***

Two-year-old children engage in a host of behaviors that ostensibly entail the attribution of mental states to other individuals. They readily deceive and lie (Chandler, Fritz, & Hala, 1989; Dunn, 1991; Newton, Reddy, & Bull, 2000), imitate intended actions (Carpenter, Akhtar, & Tomasello, 1998; Meltzoff, 1995), and initiate and engage in pretend play with others (Leslie, 1994). In one of the most convincing examples of mental-state attribution, 2-year-olds whose parents were absent when a desired toy was placed out of reach were more likely to gesture to the toy's location than were children whose parents were present; this finding suggests that 2-year-olds have an ability to modify their behavior depending on the knowledge state of others (O'Neill, 1996).

Despite the many examples of 2-year-olds' apparent appreciation of mental states, for more than 20 years the consensus has been that children younger than about 4 years of age lack a theory of mind because they have been repeatedly shown to fail the classic false-belief test (Wellman, Cross, & Watson, 2001; Wimmer & Perner, 1983), the passing of which supposedly signals a full-fledged theory of mind (Gomez, 2004). Although modifications of the test have resulted in lowering this age a little (e.g., Carlson, Moses, & Hix, 1998; Surian & Leslie, 1999), proponents of the view that a conceptual revolution around age 4 finally enables children to understand false beliefs have been undeterred (e.g., Perner & Ruffman, 2005). However, some researchers (e.g., Leslie, 1994, 2005) have advocated an early-developing theory-of-mind mechanism, and recently Onishi and Baillargeon (2005) have reported striking results suggesting that 15-month-old infants may attribute false beliefs to other individuals. In a modification of the Sally-Anne task (Baron-Cohen, Leslie, & Frith, 1985), infants looked significantly longer when an agent's behavior was incongruent than when it was congruent with a false belief. This result poses an immense challenge for proponents of the view that theory of mind undergoes a conceptual revolution when children are around 4 years of age (e.g., Gopnik & Wellman, 1992; Ruffman & Perner, 2005; Saxe, Carey, & Kanwisher, 2004).

This striking finding raises a number of important questions and, unsurprisingly, has not gone unchallenged (Perner & Ruffman, 2005; Ruffman & Perner, 2005). Onishi and Baillargeon's (2005) study was based on violation of expectation, and it is not clear whether the infants in this study attributed a specific false belief to the agent (i.e., represented the content of the agent's belief) or attributed ignorance to the agent (Hogrefe, Wimmer, & Perner, 1986). Logically, if the infants had attributed only ignorance, they should have expected the actor to search in either of the two locations (rather than in one particular location), but in reality, research suggests that when attributing ignorance to an agent, young children expect the person to get the answer wrong, rather than perform at chance (Ruffman, 1996). Thus, in Onishi and Baillargeon's study, the infants might have looked longer at the incongruent event not because they expected the agent to search specifically in the other location (in accord with a false belief), but because they did not expect the agent to search in the location shown in the incongruent event. Only if the infants expected the agent to search in the particular

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location where the agent should have believed the target object to be hidden could one attribute an understanding of false belief to the infants.

A predictive looking paradigm, in which the child's specific expectation of where the actor will search is measured, could help address this issue, but attempts to date have not been encouraging. Clements and Perner (1994) reported evidence that children younger than 2 years 11 months fail to correctly anticipate the behavior of a person with a false belief. Garnham and Ruffman (2001) reported more positive results in the age range from 2 to 4 years. However, as they did not report analyses by age, it is impossible to deduce whether any 2-year-olds succeeded on their anticipatory gaze measure, and indeed the authors themselves appear highly skeptical that they did (Ruffman & Perner, 2005).

The standard false-belief task has the disadvantage that it requires abilities other than understanding mental states (Bloom & German, 2000), and Clements and Perner's (1994) paradigm is not free from this problem either. Young children are notoriously poor at tasks requiring inhibitory control (Carlson et al., 1998; Gerstadt, Hong, & Diamond, 1994; Hood, 1995; Zelazo, Frye, & Rapus, 1996), and one explanation that has been advocated to explain the difficulty that children younger than age 4 have with the false-belief task is the so-called reality bias (Birch & Bloom, 2003; Leslie, German, & Polizzi, 2005; Mitchell & Lacohee, 1991). The reality bias occurs when the child's own knowledge about a situation interferes with his or her ability to respond accurately. In the false-belief task, the fact that children themselves know the actual location of the object makes it difficult for them to put this knowledge aside and point toward the location without the object (to indicate where the person with the false belief will look). Passing the false-belief task may depend not on any conceptual revolution, but on a more general ability to select the correct response (Leslie et al., 2005). Interestingly, when the object the agent is looking for is eaten so that it is no longer in the scene, children show evidence of false-belief understanding at age 3 (Koós, Gergely, Csibra, & Bíró, 1997).

However, as Ruffman and Perner (2005) pointed out, if the reality bias is indeed the problem that prevents 3-year-olds from passing the false-belief task, it is not clear why this bias was not also a problem for Onishi and Baillargeon's (2005) 15-month-olds; it is unlikely that these younger infants would have been immune. It is plausible, however, that the verbal nature of the standard false-belief task is what actually elicits the reality-biased response. It has previously been shown that young children have pragmatic difficulty interpreting the standard false-belief question (Siegal & Beattie, 1991). In particular, it is possible that the "where" question involved in most versions of this paradigm is prematurely interpreted by young children as referring to the location of the hidden object, rather than the location of the actor's subsequent actions (Csibra & Southgate, 2006). Such a misinterpretation would lead to an erroneous answer on the standard false-belief task, whether the required response is verbal or measured by anticipatory looking. As a nonverbal task, Onishi and Baillargeon's paradigm would not have elicited the same error. Crucially, the anticipatory looks recorded by Clements and Perner (1994) were made in response to the verbal prompt, "I wonder where he's going to look."

In the current study, we addressed these important questions by presenting 25-month-olds with a nonverbal false-belief test and using an eyetracker to measure anticipatory looking. We employed a paradigm similar to that used by Onishi and Baillargeon (2005): An actor witnessed a toy being hidden, and the toy was later removed while the actor was not attending to the scene. We familiarized children to two events in which a puppet bear hid a ball in one of two boxes and then an actor reached through one of two windows to retrieve the ball from the box. In the following test trial, the actor, having witnessed the ball being hidden in one box, became distracted and turned away from the scene. Meanwhile, the bear moved the ball from its original hiding location and took it away. Our question was, when the actor reoriented to the scene, where would children expect her to search for the ball?

As this was a nonverbal task, we needed to elicit anticipatory responses by children at the appropriate point. Therefore, the familiarization trials included a cue (a light and simultaneous sound) that signaled that the actor was about to open a window to retrieve the hidden object. We hoped that children would learn this cue and that during the test trial, when they saw and heard this cue again, it would elicit anticipatory looking toward one of the windows. Another potential problem with using a nonverbal task is that subjects are free to respond in any way they choose. In the present case, an obvious response that children could make was to look toward the box containing the ball, not necessarily because they expected the actor to search there, but because knowledge of the presence of the object and its significance in the situation might elicit saccades in that direction. To avoid such ambiguous responses, we designed our task such that the object was always removed from the scene in the test trials. Furthermore, this design rendered both search locations incorrect, and so allowed us to determine whether infants' responses were based on attributions of false belief, rather than ignorance.

To avoid the possibility that children's responses would be based on low-level cues, such as the last position of the object in the scene or the last location of the actor's attention, we included important controls embedded within two false-belief conditions. To ensure that children's expectations were not due to the last position of the object, we included one condition in which after the actor had turned away from the scene, the bear went to the other box and put the ball in that box. To ensure that children's expectations were not due to the last position of the actor's attention, we included a condition in which the bear returned to the first box (having placed the ball in the other box) to close the lid, and the actor's attention followed the bear. Because our

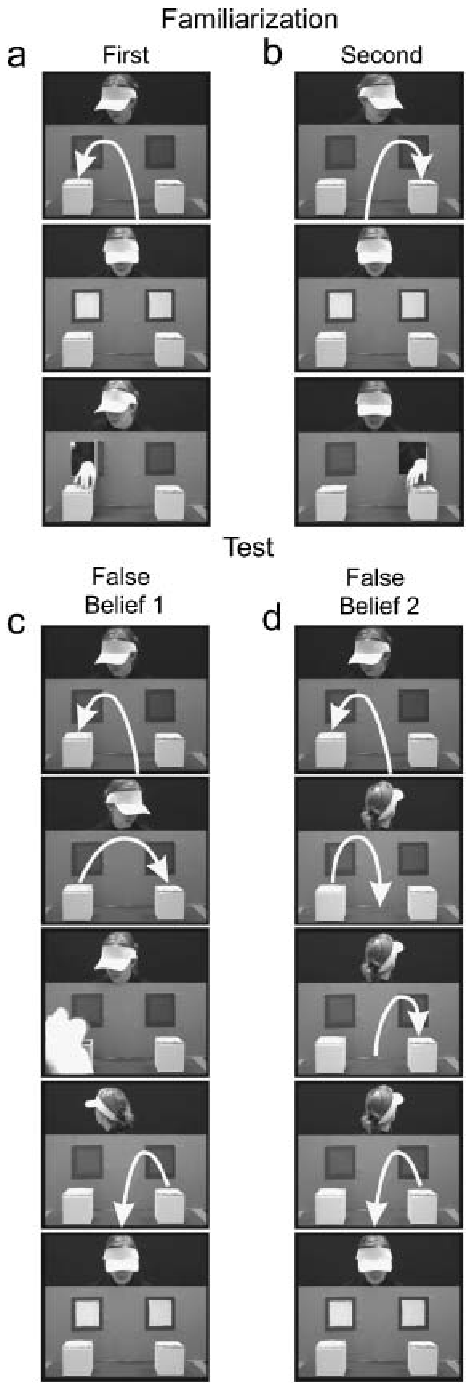

Fig. 1. Selected frames from the events used in the experiment. White arrows indicate relocation of the object (a ball). In the first and second familiarization trials, a puppet placed a ball in the left box (a) and in the right box (b), respectively. In each case, the windows were then illuminated, and the actor reached through the window to the box that contained the ball. In the test trial, the puppet initially placed the ball in the left box, but the subsequent events differed between the two false-belief conditions. In one condition (c), the puppet moved the ball to the right box and then returned to the left box to close the lid; after the actor turned around, the puppet removed the ball from the scene. In the other condition (d), the actor turned around before the puppet moved the ball to the center and then the right-hand box, and then removed the ball from the scene. In both conditions, after the puppet removed the object, the actor turned back to the scene and the windows were illuminated.

design dealt with these potential confounds within the false-belief conditions, we did not include a true-belief condition; moreover, as our design involved removing the object from the scene altogether, there was no straightforward prediction as to what kind of eye movements to expect in a true-belief condition. In addition, performance in any true-belief condition is difficult to interpret. Although correct performance is generally interpreted as reflecting the understanding of the concept of a true belief, it could also be another manifestation of the reality bias (i.e., children might look toward the correct location not because they expect the actor to search there, but because that is where the target object is located).

METHOD

Subjects

Twenty 2-year-olds participated in the experiment (8 female; mean age = 25 months 5 days, range = 24 months 5 days through 26 months 0 days). An additional 16 children were excluded because they failed to meet the criterion for inclusion (11), they looked away at the crucial moment on the test trial (2), they did not look at either window on the test trial (2), or the eyetracker could not be calibrated for them (1). Ten children were assigned to each of two false-belief conditions: FB1 (mean age = 25 months 4 days) and FB2 (mean age = 25 months 6 days).

Procedure

An integrated Tobii (Stockholm, Sweden) 1750 Eye Tracker was used to collect data on direction of gaze. The eyetracker was integrated into a 17-in. monitor, and stimuli were presented on this monitor via a computer running the Tobii's Clearview AVI presentation software.

During the experiment, each infant was seated on a parent's lap, 50 cm from a monitor on which videos were presented. After a five-point calibration was completed, the experiment began. (For technical details about the apparatus and the calibration procedure, see von Hofsten, Dahlström, & Fredriksson, 2005.) Each infant was presented with two familiarization trials and one test trial, and the general setup of the scene was the same for all three videos: An actor was seated behind a panel containing two windows, and in front of each window was an opaque box. At the beginning of each trial, a puppet appeared from the bottom of the screen and placed a brightly colored ball in one of the boxes (see Fig. 1).

The purpose of the familiarization trials was (a) to show the infants that the actor's goal was to obtain the hidden ball and (b) to teach the infants that when the windows were illuminated and a chime sounded, one of the windows was about to open. To be included in the analysis, children had to show that they understood this relationship and were motivated to anticipate the outcome; specifically, children were included only if their gaze correctly anticipated the outcome by the second familiarization trial. The familiarization trials were identical for infants in the two false-belief conditions. On the first familiarization trial, infants saw the actor watching as the puppet appeared and placed a brightly colored ball in the left-hand box (Fig. 1a). After the puppet disappeared, the two windows were illuminated, and a chime sounded simultaneously. These cues signaled to the infant that the actor would now open one of the windows. After a 1,750-ms delay, the actor reached through the left-hand window, opened the lid of the box, and retrieved the ball, smiling. The second familiarization trial was identical to the first one except that the puppet placed the ball in the right-hand box and the trial ended at the point when the actor made contact with the box (Fig. 1b). Note that in both familiarization and test trials, the actor's head always followed the movement of the puppet, so as to emphasize that she was attending to the scene. Any child who did not correctly anticipate the opening of the right-hand window on the second familiarization trial was excluded from our analysis.

Two types of test trials were employed to determine whether infants make anticipatory saccades on the basis of an attribution of false belief or on the basis of simpler rules, such as to look at the first or the last place the ball was, or the last place the actor attended.

In the FB1 condition (Fig. 1c), the puppet appeared and deposited the ball in the left-hand box. The puppet then appeared to change his mind and went back to the left box, opened the lid, retrieved the ball, and placed it in the center of the stage. The puppet then opened the right-hand box, placed the ball inside, and closed the lid. The puppet returned to the left-hand box (as the actor watched), closed the lid, and disappeared. At this point, the sound of a phone ringing was played, and the actor turned around as if attending to the sound. Note that the actor was still fully visible to the infant, but her attention was clearly directed away from the scene. As soon as the actor turned around, the puppet reappeared, opened the right-hand box, retrieved the ball, closed the lid, and left. Thus, the infant saw that the puppet had taken the ball away, but the actor would have had a false belief that the ball was still in the right-hand box. Once the puppet had disappeared, the phone stopped ringing, the actor turned back, the windows were illuminated, and the chime sounded.

In the FB2 condition (Fig. 1d), the puppet first placed the ball in the left-hand box and disappeared. Immediately, the phone began to ring, and the actor turned around. The puppet then reappeared, removed the ball from the left-hand box, and placed it in the right-hand box. The puppet then changed his mind, retrieved the object from the right-hand box, and disappeared. In this case, the child saw that the puppet had taken the object away, but the actor would have had the false belief that the object was in the left-hand box. Once the puppet had disappeared, the phone stopped ringing, the actor turned back to the scene, and the windows were illuminated and the chime sounded. (The video clips are available to view on-line at http://www.cbcd.bbk.ac.uk/people/victoria/HiddenBall.)

The actor wore a visor to prevent the infants from trying to use gaze as a cue to where she would search. Upon turning back toward the boxes in the test trials, the actor gave no cues as to where she would search, keeping her head centered so that the infants' responses could be based only on their belief about what she would do. Ten naive adults were unable to correctly identify the window that the actor would open when they watched only the portion of the test trial between the actor turning back around and the end of the light-sound cue ($p > .05$, two-choice binomial).

RESULTS

Following recording, a gaze replay file showing the exact location of each child's gaze was exported at 25 frames per second from the Clearview program. We took two measures of action anticipation. For our principal measure, we coded the location of the first saccade following the illumination of the windows. As all the infants were focused on the actor, who had just turned around at this point, a clearly discernable saccade to one of the windows was available for every child who met the criterion for inclusion in the analysis. Seventeen of the 20 infants gazed toward the correct window following illumination ($p = .003$, $p_{rep} = .982$, two-choice binomial test, two-tailed). There was no difference in performance between the two false-belief conditions, with 9 of 10 infants gazing correctly to the right-hand window in the FB1 condition and 8 of 10 infants gazing correctly to the left-hand window in the FB2 condition ($p = .5$, one-tailed Fisher's exact test).

For our second measure, we coded the amount of time each infant focused on each window. As the infants were familiarized to a delay of 1,750 ms between the onset of illumination and the opening of a window, we coded only the first 1,750 ms after onset of illumination on the test trial. The infants spent almost twice as long focusing on the correct window as on the incorrect window (*M*s = 956 ms and 496 ms, respectively). A repeated measures analysis of variance with window (correct vs. incorrect) as a within-subjects factor and condition (FB1 vs. FB2) as a between-subjects factor confirmed that the infants looked significantly longer toward the correct window than toward the incorrect window, $F(1, 18) = 5.21$, $p = .035$, $p_{rep} = .901$, $\eta_p^2 = .22$. The interaction between window and condition was not significant.

DISCUSSION

The data presented in this article strongly suggest that 25-month-old infants correctly attribute a false belief to another person and anticipate that person's behavior in accord with this false belief. Contrary to previous contentions, 25-month-olds gaze in anticipation toward a location where a person would be expected to search if he or she had a false belief (Clements & Perner, 1994; Ruffman & Perner, 2005). The direction of anticipatory looking in our data cannot be explained by the use of simpler rules, such as looking toward the first or last position of the object, the last position the actor attended, or the last location the puppet acted on. Nonetheless, the data are inevitably open to a rule-based explanation according to which the infants deployed a simple rule that agents tend to search in places where they last saw things, and did not infer any belief to the agent (Perner & Ruffman, 2005; Povinelli & Vonk, 2003). Although we find this proposal unlikely (a great many rules would be required to explain away all the different examples of infant behavior that suggest an ability to attribute mental states, as highlighted in our introduction), further research will have to address this important question.

What can account for the discrepancy between the current results and those reported by Clements and Perner (1994)? We propose that the use of a "where" question in Clements and Perner's design may have led young children to prematurely interpret the question as referring to the location of the hidden ball, rather than the person's belief about the location of the hidden ball. In the absence of a verbal prompt, 2-year-olds appear to be able to demonstrate what they really know about other people's beliefs. It is also possible that removing the object from the scene at the end of our test trials helped 2-year-olds overcome any reality bias they might have. However, this is unlikely to be the whole story, as previous studies that incorporated this modification did not demonstrate successful performance for children younger than 3 years old (Koós et al., 1997).

These results extend and corroborate the striking findings by Onishi and Baillargeon (2005) and Surian, Caldi, and Sperber (2007, this issue) indicating that 13- and 15-month-old infants are sensitive to the belief states of other individuals. Whereas these other studies leave open the question of whether infants responded on the basis of their knowledge about the content of the agent's belief or instead attributed ignorance to the agent, the current study clearly demonstrates that 25-month-olds do rely on the content of another individual's belief. Because the puppet removed the ball from the scene, both boxes were incorrect locations for the actor to search in. If 2-year-olds can attribute no more than ignorance, the infants in our study should have expected the actor to search randomly. The fact that they specifically expected the actor to search in the box that she would have searched if she had a false belief shows that 2-year-olds are able to attribute false beliefs.

Furthermore, we propose that our measure of anticipatory looking in 2-year-olds actually supports conclusions beyond what one can infer from an expectancy-violation measure. It is well known that looking-time studies reveal sensitivity to variables at earlier ages than more explicit tasks do (e.g., Baillargeon, Spelke, & Wasserman, 1985), and the reasons for this difference are hotly debated (Haith, 1998). In an attempt to account for this discrepancy, a number of researchers have proposed that different abilities may underlie success on the two types of tasks (expectancy-violation tasks and tasks requiring explicit responses, such as pointing or searching). Whereas an ability to recognize "after-the-fact incongruent events" (Keen, 2003, p. 82) may support a looking response on expectancy-violation tasks, success on more explicit measures may require the additional ability to make a prediction (Hood, Cole-Davis, & Dias, 2003). Our measure showing that 2-year-olds predicted the behavior of an actor on the basis of a false belief provides compelling evidence for an early-developing reliance on epistemic state attribution in predicting actions, and this evidence is incompatible with the position that children are able to attribute false beliefs only after undergoing a conceptual revolution between 3 and 4 years of age (Gopnik & Wellman, 1992). Our data are more consistent with the position that children's difficulties on false-belief tasks stem from performance limitations, rather than competence limitations (Surian & Leslie, 1999).

The finding that 2-year-olds predict behavior that accords with a false belief is an important one. Our results provide compelling evidence that failure on the standard false-belief task does not reflect a conceptual deficit, and researchers should be cautious in drawing conclusions from a task that cannot isolate conceptual understanding from pragmatic skills (Bloom & German, 2000). The many examples of 2-year-olds' sensitivity to other people's mental states have been puzzling in the context of their consistent failure on the false-belief task. Our data may provide the first solution to this puzzle.

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