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# Action Anticipation through Attribution of False Belief By Two-Year-Olds

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## Abstract

Two-year-olds engage in many behaviors that ostensibly require the attribution of mental states to others.  Despite this, the overwhelming consensus has been that they are unable to attribute false-beliefs at this age.  In the current study, we have used an eye-tracker to record infant's looking behaviour while they watched actions on a computer monitor. Our data demonstrate that 25-month-old infants show correct anticipation of an actor's actions that could only be predicted if they had attributed 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 others.  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 children whose parents were present, suggesting 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 twenty years the consensus has been that children below about four years of age lack a theory of mind because they have been repeatedly shown to fail the classic false belief test (Wimmer & Perner, 1983; Wellman, Cross & Watson, 2001), the passing of which supposedly signals a fully fledged theory of mind (Gomez, 2004). This robust finding has wavered somewhat as modifications have resulted in lowering this age a little (e.g. Carlson, Moses & Hix, 1998; Surian & Leslie, 1999), but proponents of the view that there is a conceptual revolution somewhere around this time finally enabling children to understand false beliefs, have been undeterred (e.g. Perner & Ruffman, 2005).  However, there has also been one position that has advocated an

early-developing 'theory of mind mechanism' (ToMM) (Leslie, 1994; Leslie, 2005) and recently Onishi & Baillargeon (2005) have reported striking results suggesting that 15-month-old infants may also attribute false beliefs to others.  In a modification of the Sally-Anne task (Baron-Cohen, Leslie & Frith, 1985), infants looked significantly longer when an agent's behavior was incongruent with a false belief than when their behavior was congruent.  This result poses an immense challenge for proponents of the developmental change view (e.g. Gopnik & Wellman, 1992; Ruffman & Perner, 2005; Saxe, Carey, & Kanwisher, 2004).

Unsurprisingly, this striking finding has not gone unchallenged (Ruffman & Perner 2005; Perner & Ruffman 2005) and raises a number of important questions. As a study based on expectation of violation with only one test trial, it is not clear whether infants in the Onishi & Baillargeon study were attributing a specific false belief to the agent (representing the content of the agents belief), or whether they were attributing ignorance (Hogrefe, Wimmer & Perner, 1986).  If infants were only attributing ignorance, logically, they should expect the actor to search in either location (rather than in one particular location), but on a task with a single test trial it is impossible to distinguish between attributions of ignorance or false belief.  In reality however, research suggests that when attributing ignorance to an agent, young children expect that the person should get the wrong answer, rather than be at chance (Ruffman, 1996).  Thus, in the Onishi & Baillargeon study, infants might look 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 didn't expect the agent to search in this location. Only if the infant expected the agent to search in the particular location where she should believe the target object is hidden could we attribute an understanding of false belief to the infant.  A predictive looking paradigm, in which the child's specific expectation of where the actor will search is measured, could help address this question, but attempts to date have not been encouraging.  Clements & Perner (1994) report evidence that children below 2 years 11 months fail to correctly anticipate the behavior of a person with a false belief. Garnham & Ruffman (2001) report 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 the anticipatory gaze measure, and indeed the authors themselves appear highly sceptical (Ruffman & Perner, 2005).

The standard false belief task also suffers from the disadvantage that it requires abilities other than understanding mental states (Bloom & German, 2000), and the Clements & Perner (1994) paradigm is not free from these problems either.  Young children are notoriously poor at tasks requiring inhibitory control (Carlson, Moses & Hix, 1998; Gerstadt, Hong, & Diamond, 1994; Hood, 1995; Zelazo, Frye & Rapus, 1996) and one explanation that has been advocated to explain the difficulty that children below four years have with the false belief task is the so-called reality bias (Birch & Bloom, 2003; 2004; Leslie, German & Polizzi, 2005; Mitchell & Lacohee, 1991).  The reality bias occurs when the child's own knowledge about a situation interferes with her ability to respond accurately.  In the false-belief task, the fact that the child herself knows the actual location of the object makes it difficult for her to put this knowledge aside and point towards the location without the object.  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, in a task where the object is eaten so that it

is no longer in the scene, children show evidence of false belief understanding at 3 years (Koós, Gergely, Csibra & Bíró, 1997). However, as Ruffman & Perner (2005) point out, it is not clear why, if this is the problem for 3-year-olds, it is also not a problem for 15-month-olds in the Onishi & Baillargeon paradigm. If the reality bias is indeed the problem preventing three-year-olds from passing the false belief task, it is unlikely that younger infants would be immune. It is plausible, however, that it is the verbal nature of the standard false belief task that 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 all versions of this paradigm is prematurely interpreted by young children as referring to the location of the hidden object, rather than 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, the Onishi & Baillargeon paradigm would not elicit the same error. Crucially, the anticipatory looks recorded by Clements & 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 young two-year-olds with a non-verbal false-belief test using an eye tracker to measure anticipatory looking. We employed a paradigm similar to that used by Onishi & Baillargeon (2005), in which an actor witnesses the hiding of a toy at a location, which is later removed while the actor is not attending. We familiarized children to two events in which a puppet bear hid a ball in one of two boxes and then an actor reaches through one of two windows to retrieve the ball. This was followed by a test trial in which, having witnessed the ball being hidden in one box, the actor becomes distracted and turns away from the scene. Meanwhile, the bear moves the ball from its original hiding location and takes it away. Our question was, when the actor reorients to the scene, where does the child expect that she will search for the ball?

As this was a nonverbal task, in order to elicit anticipatory responses by the child at the appropriate point, the familiarization trials included a cue (a light and simultaneous sound) that would signal the impending opening of a window to retrieve the hidden object. It was hoped that children would learn this cue and that during the test trial, when they see this cue again, it will elicit anticipatory looking from the child. Another potential problem with using a non-verbal task is that children are free to respond in any way they choose. An obvious response that the child could make is to look towards the box containing the ball, not necessarily because they expect the actor to search there, but because the knowledge of the presence of the object and its significance in the situation may elicit saccades in that direction. In order to avoid such ambiguous responses, we designed our task such that the object was always removed from the scene in the test trials. Furthermore, such a design renders both search locations incorrect, and so would allow us to more strongly determine whether infant's responses are based on attributions of false belief, rather than ignorance.

To avoid the possibility that children's responses are 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, our design included a number of important controls in terms of counterbalancing these factors across two types of false-belief conditions. In order to ensure that children's expectations were not due to the last position of the bear, one

condition included a situation in which after the actor had turned away from the screen, the bear then went to the other box and put the ball in that box.  In order to control for the last position of the actors attention, another condition incorporated a scenario in which the bear had to return 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 design has dealt with these potential confounds within the false belief conditions, we did not include a true belief condition as, since our design involved removing the object from the scene altogether, there is no straightforward prediction as to what kind of eye movements we should expect in a true belief condition.  In addition, performance on the true belief condition is itself difficult to interpret.  Whilst 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., the children would look towards the correct location not because they expect the actor to search there, but because that is where the target object is located).

**Method**

*Participants*

Twenty two-year-olds participated in the experiment (12 male, 8 female, mean age: 25;5, range 24;5 – 26.0).  An additional 16 children were excluded due to failing to meet the criterion for inclusion (11), looking away at the crucial moment on the test trial (2), not looking at either door on the test trial (2) and an inability to get a calibration (1). Ten children were assigned to a false-belief 1 condition (mean age; 25;4) and 10 were assigned to the false-belief 2 condition (mean age: 25;6).

*Procedure*

An integrated Tobii 1750 Eye Tracker was used to collect data on direction of gaze.  The eye tracker is integrated into a 17" TFT monitor, and stimuli were presented on this monitor via a PC running the Clearview AVI presentation software.

During the experiment, the infant was seated on a parent's lap, 50 cm from the presentation monitor.  A five-point calibration was carried out for each infant, and following calibration, the experiment began.  (For technical details about the apparatus and the calibration procedure, see von Hofsten, Dahlström, and Fredriksson, 2005). Each infant was presented with two familiarization trials and one test trial, and the general set-up was the same for all three video clips.  An actor was seated behind a panel containing 2 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 coloured object in one of the boxes (Figure 1).

The purpose of the familiarization trials were 1) to show the infant that the actor's goal is to obtain the hidden object and 2) to teach the infant that when they see the doors illuminate and hear the simultaneous chime, one of the doors is about to open.  To be included in the analysis, children had to show evidence that they understood this relationship and were motivated to anticipate the outcome by evidencing correct anticipation on 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 coloured object in the left-hand box (Figure 1A). Then the puppet disappeared,

both doors were illuminated and the 'chime' sound simultaneously emitted.  These cues were included so as to signal to the infant that the actor would now open one of the doors.  After a 1750 ms delay, the actor reached through the left-hand window, opened the box lid and retrieved the ball, smiling.  The second familiarization trial was identical to the first one except that the puppet placed the object in the right-hand box and the trial ended at the point where the actor made contact with the box (Figure 1B). Note that in both familiarization and test trials, the actor's head always followed the movement of the puppet, in order 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 prepared to test whether infants make anticipatory saccades based on an attribution of false belief, or on simpler rules such as the first or the last place the object was, or the last place the actor attended. In addition, to eliminate the possibility that they would simply look towards the box containing the object, we made sure that the object was no longer present at the time of action prediction.

   For the false-belief 1 condition (Figure 1C), children saw the puppet appear and deposit the object 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 object and placed it in the centre of the stage.  The puppet then opened the right-hand box, placed the object inside, and closed the lid.  The puppet returned to the left-hand box (followed by the actor's attention), closed the lid, and disappeared.  At this point, a phone ringing sound was played and the actor turned around as if attending to the sound.  Note that the actor was still fully visible to the child, but her attention was clearly directed away from the scene.  As soon as the actor turned around, the puppet re-appeared, opened the right-hand box, retrieved the object, closed the lid and left.  In this case, the child saw that the puppet had taken the object away, but the actor must have had a false-belief that the object was in the right-hand box.  Once the puppet had disappeared, the phone stopped ringing, the actor turned back, and the windows were illuminated.

   For the false-belief 2 condition (Figure 1D), the puppet first placed the object in the left-hand box and disappeared.  Immediately, the phone began to ring and the actor turned around.  The puppet then reappeared, removed the object 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 must have had the false-belief that the object was in the left-hand box. Once the puppet has disappeared, the phone stopped ringing, the actor turned back to the scene, and the windows were illuminated.  See Figure 1 for details.  (The video clips are available to view online at http://www.cbcd.bbk.ac.uk/people/victoria/HiddenBall).

   The actor wore a visor to prevent infants from trying to use gaze as a cue to where the actor would search.  Upon turning back towards the boxes in the test trials, the actor gave no cues to where she would search, keeping her head centred so that the infants responses could only be based on their belief about what the person would do.  Ten naïve 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 extinction of the light ($p > .05$, 2-choice binomial).
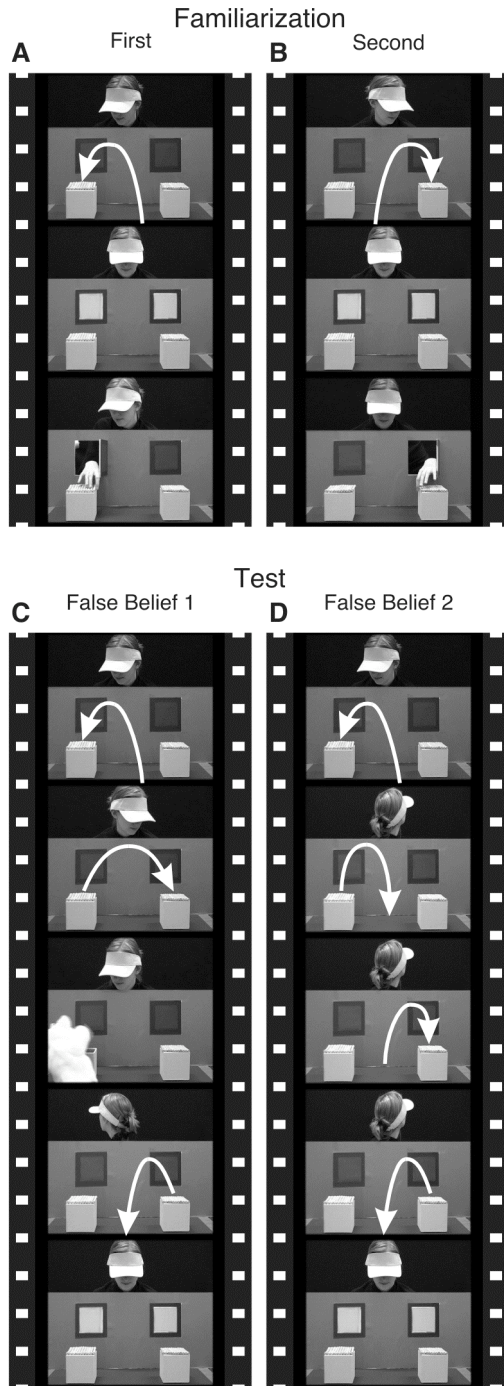
**Figure 1**   Selected frames from the events used in the experiment.  White arrows indicate object relocation.  Infants were familiarized to two events in which (A) a puppet places a ball in the left box and (B) then in the right box.  After each hiding, the doors illuminate and the actor reaches through the corresponding window. In the test trial, the puppet initially places the object in the left box. In the false belief1 condition (C) the puppet then moves the object to the right box, after which the person turns around and the puppet removes the object from the scene. In the false belief 2 condition (D) the person turns around and then the puppet moves the object to the right hand box and

then removes the ball from the scene.  For both test trial types, after the puppet has removed the object, the actor turns back to the scene and the doors are illuminated.

## Results

Following recording, a gaze replay AVI showing the exact location of the child's gaze was exported at 25 fps from the Clearview programme.  We took two measures of action anticipation.  As our principal measure, we coded the location of the first saccade following the illumination of the windows.  As all children 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.  17 out of 20 infants gazed towards the correct window following illumination ($p = .003$, $p_{rep} = .982$, two-choice binomial test, two-tailed).  There was no difference between performance on the two false-belief conditions with 9/10 infants gazing correctly to the right-hand door on the false-belief 1 condition and 8/10 infants gazing correctly to the left-hand door on the false-belief 2 condition ($P = .5$, one-tailed Fisher's exact test).

Secondly, we coded the amount of time spent focused on each window for each child.  As infants were familiarized to a delay of 1750 ms between the onset of illumination and the opening of a window, we coded only the first 1750 ms after onset of illumination on the test trial.  Infants spent almost twice as long focusing on the correct window than the incorrect window: an average of 956 ms and 496 ms respectively.  A repeated measures ANOVA with location as a within-subjects factor and condition (FB1 vs. FB2) as a between subjects factor confirmed that infants looked significantly longer towards the correct window than 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 paper strongly suggest that 25-month-old infants correctly attribute a false belief to another person and anticipate their behavior in accord with this false belief.  Contrary to previous contentions, 25-month-olds gaze in anticipation to a location where a person would appear if they had a false belief (Clements & Perner, 1994; Ruffman & Perner, 2005). The direction of anticipatory looking cannot be explained by the use of simpler rules such as 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 we present is inevitably open to a rule-based explanation in which behavior is explained as the consequence of the infant having deployed a simple rule that agents tend to search in places where they last saw things, without inferring any 'belief' to the agent (Perner & Ruffman, 2005; Povinelli & Vonk, 2003).  Whilst we find this proposal unlikely (a great many rules would be required to explain away all the different examples of infant behaviour highlighted in our introduction, which suggest an ability to attribute mental states), further research will have to address this important question.

What can account for the discrepancy in performance between the current result and those reported by Clements & Perner (1994)?  We propose that the presence of a 'where' question in the Clements & Perner 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 hidden ball.  In the absence of a verbal prompt, two-year-olds are able to demonstrate what they really know about others' beliefs.  It is also possible that removing the object from the scene at the end of the trial helped two-year-olds overcome any 'reality bias' they may have.  However, this is unlikely to be the whole story as previous studies that incorporated this modification did not uncover successful performance below three-years (Koós et al., 1997).

These results extend and corroborate the striking findings by Onishi & Baillargeon (2005) and Surian, Caldi & Sperber (in press) that 13- and15-month-old infants are sensitive to the belief state of others.  Whereas these studies leave open the question of whether or not infants are responding on the basis of their knowledge about the content of the agent's belief, or whether their abilities are limited to attributing ignorance to the agent, the current study clearly demonstrates that 25-month-olds do rely on the content of another's belief.  Because the object was removed from the scene by the puppet, both boxes were incorrect locations for the actor to search in.  If ignorance was the limit of two-year-olds' attributions, they should expect the actor to search randomly.  The fact that they specifically expected the actor to search in the box that she would if she had a false belief shows that two-year-olds are able to attribute false-beliefs.

Furthermore, we propose that our measure of anticipatory looking in two-year-olds actually goes beyond the limits of what one can infer from an expectancy-violation measure.  It is well known that looking time studies reveal sensitivity to variables at an age where more explicit tasks cannot (e.g. Baillargeon, Spelke & Wasserman, 1985), the reasons for which 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.  Whereas an ability to recognize "after-the-fact incongruent events" (Keen, 2003, p. 82) may support longer looking 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 two-year-olds predict the behavior of an actor on the basis of a false-belief provides compelling evidence for an early developing reliance on epistemic state attribution for action prediction, one that is incompatible with the position that children must undergo a conceptual revolution between 3 and 4 years of age allowing them to finally attribute false-beliefs (Gopnik & Wellman, 1992). Rather, our data may be more consistent with the position that children's difficulties on false belief tasks stem from performance, rather than competence, limitations  (Surian & Leslie, 1999).

The finding that two-year-olds predict the behavior of an actor in accord 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 two-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.

## Acknowledgements

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