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Attributing False Beliefs About Object Identity Reveals a Signature Blind Spot in Humans' Efficient Mind-Reading System

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Abstract

How can human beings make significant but cognitively taxing inferences about others' beliefs yet also effectively "mind read" in fast-moving social situations? We tested the idea that humans have two mind-reading systems: a flexible system and an efficient system that can make fast calculations because it has natural blind spots to the kinds of input it processes. We showed that the automatic gaze anticipations of 3-year-olds, 4-year-olds, and adults displayed a signature blind spot specific to calculating an actor's false belief about object identity—a calculation that required the complex understanding that an object can be interpreted differently depending on one's visual perspective. Participants' deliberate verbal inferences demonstrated significant flexibility in calculations of another person's beliefs. Our results show that quick, efficient mind reading eschews conceptual sophistication.

Keywords

theory of mind, cognitive development, social cognition

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In a split second, a footballer shifts to the right as if he is playing the ball that way, and when the goalkeeper moves to the right, the player surprises the goalkeeper by kicking the ball to the left. Elsewhere, a jury spends time deliberating a case involving a boy who shot his sister while playing with a gun: whether there was premeditation, whether the boy saw or believed that the bullet chamber was empty, or whether he was just careless. The footballer and jury in these examples are demonstrating virtues of mind reading that allow for fast-moving social interaction and complex psychological reasoning.

Mind reading is pervasive in social life, yet there is a sharp puzzle regarding the nature and emergence of mind reading in young children. A dominant measure of human mind-reading ability—the false-belief test—captures people's understanding that others can act on the basis of their mental representation of the world even when that representation does not match reality. In the standard test (Wimmer & Perner, 1983), a boy (Maxi) puts chocolate in a drawer, after which his mother surreptitiously moves the chocolate to a cupboard; participants are then asked where Maxi will search for his chocolate. Adults recognize Maxi's false belief and predict that he will look in the drawer.

Decades of research have shown that children pass this standard false-belief test starting when they are 4 years old (Wellman, Cross, & Watson, 2001). However, 3-year-olds fail, replying that Maxi will search in the cupboard, where the chocolate really is. A classic explanation for this pattern is that a conceptual shift occurs during the preschool years, when children's understanding of mind changes from being nonrepresentational to being representational (Perner, 1991). Recent studies that have indirectly measured children's understanding of mind on the basis of their spontaneous behavior in the test situation complicate this developmental story. When children reach 3 years of age, the location where they verbally predict Maxi will search for the chocolate dissociates from the location where they anticipate Maxi will search for the chocolate: Preschoolers first look at the drawer, despite answering that Maxi will search in the cupboard (Clements & Perner, 1994; Wang, Low, Jing, & Qinghua, 2012).

In a landmark study, 15-month-olds stared longer when an actor searched for an object in a location that did not match what would be expected on the basis of her (false) belief about its whereabouts; infants thus behave as though they appeal to other people's beliefs when interpreting those people's goal-directed pursuits (Onishi & Baillargeon, 2005). Studies

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measuring looking times have suggested that children have the ability to understand other people's beliefs by the middle of the first year of life (Kovács, Téglas, & Endress, 2010; Southgate, Senju, & Csibra, 2007). Such findings raise a startling paradox: How can infants, toddlers, and young preschoolers, who consistently fail to demonstrate any mind-reading ability on the standard false-belief test, nevertheless appear to track others' beliefs on indirect measures?

The early-mind-reading account assumes that infants have an innate representational understanding of belief (Onishi & Baillargeon, 2005). Direct verbal prediction in the standard false-belief test makes great demands on abilities that develop more slowly than mind reading, such as inhibition and response selection; verbal-prediction measures thus underestimate early mind-reading ability. Indirect measures of mind reading based on looking times reveal early competency by tapping only the belief-representation process (Baillargeon, Scott, & He, 2010). In contrast to the early-mind-reading account is the behavior-rule account, which holds that looking times indicate shallow causal understanding (Perner, 2010; Perner & Ruffman, 2005). Eye movements alone may reflect the learned behavior rule that people search for an object in the place where they last saw it rather than reflecting a deep analysis in terms of mental states. According to the behavior-rule account, the mind-reading system is most tellingly distinguished from this behavior-reading system when people verbally predict and justify others' goal-directed actions across diverse test scenarios (Low & Wang, 2011). We propose that neither the early-mind-reading account nor the behavior-rule account is fully adequate—the paradox is resolved by an account of not one but two mind-reading systems.

Consider the reasoning exhibited by the jury members and the footballer again. The jury members consider the defendant's belief in combination with his other mental states in order to reach a verdict—mind reading is flexible. The footballer faking a pass quickly anticipates the goalkeeper's action without engaging in unbounded inferences about his beliefs that would interfere with playing the game itself—mind reading is efficient. One possibility is that dual and contradictory cognitive requirements of flexibility and efficiency in mind reading point to the existence of two mind-reading systems (Apperly, 2011).

Evidence that the development of the ability to make direct predictions about false beliefs, but not the ability to indirectly anticipate false beliefs, correlates with the development of language and executive functioning dovetails with a two-systems proposal (Low, 2010). By this account, a flexible and conscious but inefficient mind-reading system supports direct, verbal false-belief predictions; this system ascribes complex mental states (e.g., beliefs) to people and is emergent from age 4 as language, executive functions, and meta-representational skills develop (Apperly, 2011; Wang et al., 2012). An efficient, unconscious, and inflexible mind-reading system supports indirect looking responses; this system is shared by infants and adults and ascribes the belief-like state of *registration*, which is a proxy for belief (Apperly & Butterfill, 2009; Butterfill & Apperly, in press). An individual is said to register an object at a location if he or she recently encountered the object at that location and acts as if the object is there. Automatic responses to certain mind-reading tasks (e.g., tasks investigating false beliefs about the location, contents, or properties of objects) could be supported by a distinct system that tracks agents' registration. Another possibility is that the efficient system is based on an understanding of social interactions in terms of behavior rules (which may make it fast, in line with the observation that tricking one's opponent in a sports game needs to be quick).

So how can we determine, by measuring eye movements, whether children and adults are tracking registration instead of belief? The two-systems proposal contends that efficiency is gained by surrendering flexibility and makes the unique prediction that there are natural, signature blind spots in the efficient mind-reading system. One blind spot in representing registrations is revealed through mistakes about identity (Apperly & Butterfill, 2009). Consider the following premises relating to Lois Lane looking for Clark Kent:

1. Lois Lane believes that Superman is in the sky.
2. Superman is Clark Kent.
3. Therefore, Lois believes that Clark Kent is in the sky.

In terms of belief, the inference at Step 3 is invalid: Although Lois may hold a belief about Superman, she does not necessarily know that Clark Kent is Superman. Compare the inference in the case of registration:

1. Lois registers <Superman, sky>.
2. Superman is Clark Kent.
3. Lois registers <Clark Kent, sky>.

Given that registration concerns relations among objects, not propositions about them (Butterfill & Apperly, in press), Step 3 is valid here because it does not involve ascribing a belief to Lois. An individual who represents Lois registering <Superman, sky> will not understand why Lois continues looking for Clark Kent because registering <Superman, sky> and registering <Clark Kent, sky> are equivalent. Critically, an individual who represents belief *as such* (i.e., as a relation concerning an agent, the attitude of believing, and a propositional representation of what is believed) will have no problem understanding that there are different ways of thinking about the same thing, such that the validity of one ascription does not require the validity of another.

Although young children show nonverbal sensitivity to facts in false-belief tests involving object location, little is known about how they would apply their mind-reading ability to tests involving object identity. The discovery of signature blind spots in children's and adults' ability to ascribe false beliefs about object identity—when these ascriptions are automatic—would make a powerful case that more than one mind-reading system is needed to efficiently track and flexibly represent beliefs. We tested this idea with 3- and 4-year-olds and adults.

According to the early-mind-reading account, a full-blown mind-reading system that supplies a representational understanding of belief can be revealed using simple testing procedures: Preschoolers should exhibit accurate looking anticipations but make inaccurate verbal predictions across false-belief location and identity tests. The behavior-rule account makes no particular prediction about how children and adults might react across a range of false-belief tests. In contrast to both the early-mind-reading account and the behavior-rule account, the two-systems account makes the unexpected and specific prediction that there should be signature blind spots when automatic belief ascriptions involve the particular way in which an agent sees an object. First, both preschoolers and adults should show inaccurate looking anticipations in the object-identity test but accurate looking anticipations in the object-location test. Second, because the ability to predict false beliefs regarding object location and the ability to predict false beliefs regarding object identity should develop in step and emerge by the age of 4 years, 4-year-olds and adults should make accurate verbal predictions in both types of test. Third, 3-year-olds should exhibit correct anticipations but make incorrect verbal predictions on the location test, whereas 4-year-olds and adults should show the reverse pattern on the identity test.

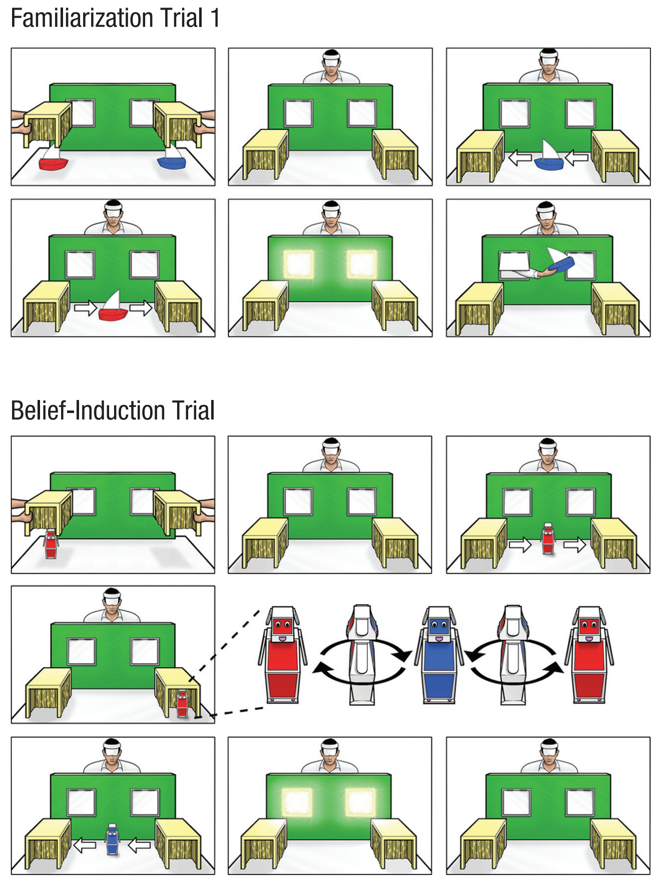


Fig. 1. Illustration of key scenes in a familiarization trial and a belief-induction trial in one version of the identity test (in this example, the actor displays a preference for blue in the familiarization trial). In the familiarization trial, participants saw two boxes, which were lifted to reveal a red boat under the left-side box and a blue boat under the right-side box. The blue boat traveled to the left-side box, and then the red boat traveled to the right-side box. After two windows above the boxes lit up and a beep sounded, the actor reached through the left-side window, retrieved the blue boat to show he had a preference for blue, and smiled. In the belief-induction trial, the boxes were lifted to reveal a dog-robot toy, which had one red side and one blue side, underneath the left-side box, with its red aspect facing participants. The actor watched the dog robot travel to the right-side box, where, in a recessed chamber visible only to the participants, the dog robot spun to reveal its blue aspect, spun again to reveal its red aspect, and repeated the spins. Finally, with its blue aspect facing participants and red aspect facing the actor, the dog robot traveled to the left-side box, and the windows were illuminated as a beep sounded.

Method

Sixteen 3-year-olds (9 males, 7 females; mean age = 41.56 months, age range = 37–47 months) and sixteen 4-year-olds (7 males, 9 females; mean age = 53.50 months, age range = 50–59 months) from local kindergartens participated after we obtained informed consent from their parents. Twenty university students (10 males, 10 females; mean age = 23.47 years, age range = 19–38 years) participated after providing informed consent. Participants were randomly assigned to view one of four filmed versions of an identity test and one of two filmed versions of a location test (all films had frame rates of 25 frames per second; order of presentation was counterbalanced between participants). Participants watched the tests on a TV screen while a video camera above the screen recorded their eye movements.

Identity Test Version 1 (see Fig. 1) included four familiarization trials and one belief-induction trial. (Supplemental Videos S1 and S2, in the Supplemental Material available online, show the whole sequence of the first familiarization trial and the belief-induction trial.) At the start of the first familiarization, participants saw a screen with two windows, each with a box beside it; the sides of the boxes that faced each other and faced the participants were covered with fringe. The boxes were lifted to reveal a red boat underneath the left-side box and a blue boat underneath the right-side box and then were lowered. Next, participants saw a male actor wearing a visor and standing behind the screen. The blue boat traveled from the right-side box to the left-side box, and then the red boat traveled from the left-side box to the right-side box. The actor followed the boats' movements with his head, after which he kept his head centered. Both windows then lit up while a beep sounded simultaneously; this cue informed participants that the actor was about to reach through one of the windows to retrieve an object. After a 1,750-ms delay, the actor reached through the window on the left side of the screen into the left-side box, retrieved the blue boat to show participants that he had a preference for blue, and smiled.

The second, third, and fourth familiarization trials were similar to the first except as follows. In these trials, the boxes were lifted to reveal racing cars, ducks, and buggies, respectively. The last two familiarization trials ended at the point when the actor reached through a window to reach inside the box containing the blue object. In the second and third familiarization trials, the blue object was initially under the left-side box and traveled to the right-side box, and the red object was under the right-side box and traveled to the left-side box. The actor always reached for the blue object. By the third familiarization trial, all participants looked at the right-side window in anticipation of the actor's reaching through that window to retrieve the blue object from the right-side box. Thus, we were confident that during the belief-induction trial, the cue would elicit anticipatory looking to one of the sides.

The belief-induction trial, which was the same for all versions of the identity test, involved a dog-robot toy that, unusually, had a face and body that were blue from one angle and red from another. In a relevant study, Scott and Baillargeon (2009) used two toys (an indivisible one-piece toy penguin and a stackable two-piece toy penguin) to test infants' ability to infer an agent's false belief about which toy she was facing. However, partly because the two penguins were in the scene at all times, this method was criticized as providing evidence only that infants reasoned about the *types* of objects present and not necessarily that infants ascribed false beliefs to the actor that were about object identity per se (Butterfill & Apperly, in press; Zawidzki, 2011). To avoid this problem in our belief-induction trials, we used only one object with two aspects (identities) that could not be seen at once.

At the outset of the belief-induction trial, while the actor was absent, the boxes were lifted to reveal the dog-robot toy (with its red face and body facing participants) underneath the left-side box. There was nothing underneath the right-side box. The boxes were then lowered. The actor entered, and he followed the dog robot with his head as it traveled (with its red aspect facing participants) from the left-side box to the right-side box, after which the actor kept his head centered. Participants thus saw only the red aspect of the dog robot, whereas the actor saw only the blue aspect. The dog robot then silently emerged in a recessed chamber in the right-side box, where it was visible only to the participants and not to the actor. In this viewing chamber, the dog robot, with its red aspect facing participants, spun 180° to reveal its blue aspect, and then spun 180° again to reveal its red aspect. These spins were repeated once more. Finally, the dog robot, with its red aspect facing participants, retreated from the recessed chamber to move back behind the fringe under the right-side box. The actor followed the dog robot with his head as it traveled from the right-side box to the left-side box, but this time, the actor saw the red aspect of the dog robot and participants saw the blue aspect of the dog robot as it moved into the box. At this point, the actor kept his head centered (to give no clues as to where he would search), and the windows were illuminated as a beep sounded.

Regarding belief ascription, there is reason for the actor to expect another (blue) dog robot to be inside the right-side box. To appreciate that the actor has reason to search in the right-side box, participants would need to ascribe to him a false belief about the object's identity. For the first 1,750 ms following the cue, we determined whether participants showed anticipatory looking to the left side or to the right side and measured looking duration. After that period, the video playing on the TV screen was paused, and the experimenter asked two questions: a direct false-belief-prediction question ("Which box will the man look in?") and a control question assessing memory ("Which box is the dog robot in?").

Identity Test 2 was the same as Identity Test 1 except that in the belief-induction trial, the dog robot was initially under the right-side box. In Identity Tests 3 and 4, the actor had a preference for red in the familiarization trials, and the blue aspect of the dog robot faced participants at the outset of the belief-induction trial.

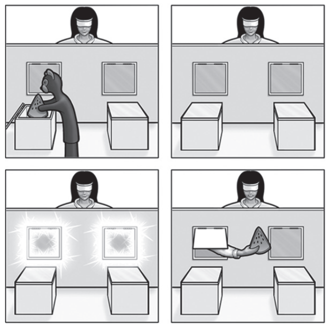
The object-location test (Southgate et al., 2007) consisted of two familiarization trials and one belief-induction trial (Fig. 2). In each familiarization trial, participants saw a female actor behind a screen. As in the identity test, the screen had two windows around them, and the actor could reach through either window into a box underneath; in the object-location test, however, the boxes had lids. In the first familiarization trial in Location Test 1, a puppet monkey placed a slice of watermelon in the left-side box, closed the lid, and left. After 1,750 ms, the actor reached through the left-side window, opened the lid of the left-side box, retrieved the watermelon, and smiled. The second familiarization trial was similar except the puppet hid a tomato instead of a slice of watermelon, and the trial ended when the actor reached through the left-side window and touched the lid of the left-side box.

By the second familiarization trial, all participants correctly gazed at the left side of the screen in anticipation of the actor's opening the left-side window and reaching toward the left-side box. In the belief-induction trial, the puppet reappeared, placed a ball in the left-side box, and disappeared. A telephone rang, and the actor turned away from the scene and picked up the phone, keeping her back turned toward the participants. The puppet then reappeared, transferred the ball from the left-side box to the right-side box, and exited. Thus, there was reason for the actor to expect that the object was still in the left-side box. After the puppet exited, the actor turned around and the windows illuminated as a beep sounded. The actor kept her head centered, giving no clue as to where she would look. Location Test 2 was the same as Location Test 1 except that hiding places in the familiarization and belief-induction trials were reversed.

For the first 1,750 ms following the cue in the belief-induction trial, we determined whether participants showed anticipatory looking toward the left or the right side of the screen and measured looking duration. At the end of the trial, the video was paused, and the experimenter asked two questions: a direct false-belief-prediction question ("Which box will the woman look in?") and a control question assessing memory ("Which box did the monkey put the ball in first?").

All participants correctly answered the control questions. One rater coded all recordings for anticipatory looking during

Familiarization Trial 1



Belief-Induction Trial

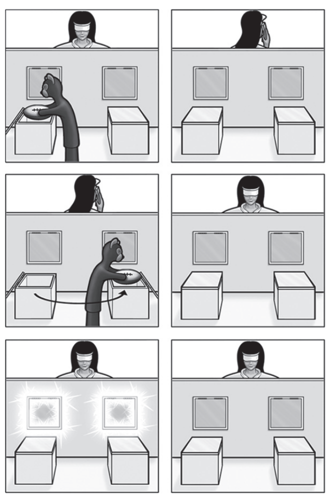


Fig. 2. Illustration of key scenes in a familiarization trial and a belief-induction trial in one version of the location test. In the familiarization trial, participants saw a female actor behind a screen that had two windows, each with a box underneath. A puppet monkey placed a slice of watermelon in the left-side box, closed the lid, and left. The actor then reached through the left-side window, retrieved the watermelon from the left-side box, and smiled. In the belief-induction trial, the puppet reappeared, placed a ball in the left-side box, and disappeared. The actor turned away from the scene to answer a phone call; while her back was to the participants, the puppet reappeared, transferred the ball to the right-side box, and exited. The actor then turned around, and the windows illuminated as a beep sounded.

the first 1,750 ms following the cue in the belief-induction trials for both tests. The coding was done by playing back each recording in slow motion and scoring gaze direction on a frame-by-frame basis (calculated looking times were accurate to 0.04 s; Low, 2010; Ruffman, Garnham, Import, & Connolly, 2001). A separate rater coded 20% of the recordings; the two raters agreed 100% of the time as to whether or not participants looked toward the correct location first and how long they looked toward it.

Results

Results revealed no effects of gender or presentation order. In the location test, all of the 4-year-olds and the majority of 3-year-olds (94%) and adults (90%) showed anticipatory looks toward the correct location—a greater percentage for each age group than would be expected by chance (binomial test, ps ≤ .001). Performance was strikingly different in the identity test, such that the majority of participants in each age group first looked to the wrong location: Only 6% of 3-year-olds, 6% of 4-year-olds, and 25% of adults showed anticipatory looks toward the correct location—percentages that were all below chance (binomial test, ps > .05). We found this pattern of accurate first looks in the location test but inaccurate first looks in the identity test among 3-year-olds (88%; Wilcoxon $Z = -3.74$), 4-year-olds (94%, $Z = -3.87$), and adults (65%, $Z = -3.61$; all ps < .0001). Only 6% of 3-year-olds, 6% of 4-year-olds, and 25% of adults showed anticipatory looks toward the correct location in both tests.

We analyzed duration of looking—based on a differential looking score (Senju, Southgate, & Frith, 2009)—over the 1,750-ms window following the cue in the belief-induction trial in each test. An analysis of variance (ANOVA) was conducted for each age group, with test (location vs. identity) as a within-subjects factor. Looking times for gazes to the correct side were longer in the location test than in the identity test among 3-year-olds ($M = 536$ ms vs. $M = -409$ ms), $F(1, 15) = 26.65$, $p < .0001$, $\eta_p^2 = .64$; 4-year-olds ($M = 410$ ms vs. $M = -646$ ms), $F(1, 15) = 56.59$, $p < .0001$, $\eta_p^2 = .79$; and adults ($M = 699$ ms vs. $M = -293$ ms), $F(1, 19) = 20.56$, $p < .0001$, $\eta_p^2 = .52$.

Accuracy in making direct verbal predictions increased as a function of age in the location test (3-year-olds: 31%; 4-year-olds: 75%; adults: 100%), $\chi^2(2, N = 52) = 20.64$, $p < .0001$, and in the identity test (3-year-olds: 13%; 4-year-olds: 56%; adults: 95%), $\chi^2(2, N = 52) = 24.81$, $p < .0001$). Prediction responses showed a consistent pattern of failures among 3-year-olds (69%), $\chi^2(1, N = 16) = 5.03$, $p < .05$, a consistent pattern of successes among 4-year-olds (56%), $\chi^2(1, N = 16) = 6.86$, $p < .01$, and near-ceiling performance among adults (95%).

Three-year-olds (63%) showed significant dissociation between anticipatory looking and verbal predictions in the location test, displaying correct first looks despite erring in verbal predictions (Wilcoxon $Z = -3.16$, $p < .01$). However, 3-year-olds showed no such dissociation in the identity test ($Z = -1.00$, $p > .01$); 88% failed at both anticipatory looking and verbal prediction in the identity test. We found marginal evidence for an anticipation-prediction dissociation in the location test among 4-year-olds ($Z = -2.00$, $p = .05$), 75% of whom gave correct anticipatory responses and made correct verbal predictions. The majority of adults (90%) also showed correct anticipatory responses and made correct verbal predictions in the location test ($Z = -1.41$, $p > .05$). In contrast, in the identity test, half or more of 4-year-olds and adults showed a reverse anticipation-prediction dissociation pattern (4-year-olds: $Z = -2.83$, $p < .01$; adults: $Z = -3.74$, $p < .0001$). In the identity test, 50% of 4-year-olds made correct verbal predictions but erred in their first-look anticipations, 44% made incorrect predictions and showed incorrect anticipatory looking, and 6% made correct predictions and showed correct anticipatory looking. Among adults, 70% made correct predictions but erred in their anticipatory looking, 5% made incorrect predictions and showed incorrect anticipatory looking, and 25% made correct predictions and showed correct anticipatory looking.

Discussion

All groups in our study showed mind-reading ability: Participants were sensitive to facts about another person's beliefs, as evidenced by accurate automatic eye movements when they anticipated that person's actions in the location test. Despite that ability, anticipatory looking among the three different age groups revealed the same signature blind spot in the tracking of *how* the agent saw a particular object, as demanded by the identity test. Supporting a two-systems account (Apperly & Butterfill, 2009), our findings indicate that the efficient mind-reading system eschews consideration of the particular way in which an object is represented by an agent, something that is required for a normative understanding of belief. Four-year-olds and adults had no difficulty making correct verbal predictions about the agent's actions, a result suggesting that effortful verbal reasoning is supported by a flexible mind-reading system (see also Perner, Mauer, & Hilderbrand, 2011).

The single-system early-mind-reading account might explain our results as reflecting the greater degree of executive ability needed to solve the identity test compared with the location test. But why should the identity test require more inhibitory effort than the location test? Although it is possible that preschoolers' inhibitory control is not sufficiently developed to inhibit incorrect gazing on the identity test, this would not explain why adults with mature executive functioning should also show incorrect anticipatory looks on the identity test. Such an explanation also cannot easily account for 4-year-olds' accurate verbal predictions but erroneous anticipatory looking in the identity test; the single-system mind-reading account assumes that direct verbal prediction, not indirect looking, is encumbered by executive demand.

What about the behavior-rule account? This account, in explaining the apparent sophistication of children's anticipatory looking (and even verbal predictions) in different test situations, suggests that humans may draw inferences from underlying patterns in people's actions to employ some range of behavior rules that allow them to make generalizations when reasoning. A determined behavior-rule theorist could conjure up some ad hoc way to account for our findings: For example, the rule "if an object is blue, the agent will reach for it" could explain incorrect anticipatory looks toward the box containing the object in the identity test. However, this would not explain why 4-year-olds and adults did not follow that rule when making verbal predictions in the identity test: They (correctly) predicted that the agent would reach into the empty box. Critically, the behavior-rule account does not necessarily predict that there should be one type of anticipation-prediction dissociation in the location test and the reverse type of anticipation-prediction dissociation in the identity test.

We therefore prefer the two-mind-reading-systems interpretation of our findings. First, the cognitive problem at the heart of mind reading involves a tension between flexibility and efficiency (Apperly, 2011). The ability to infer or explain other people's beliefs requires an understanding of the normative aspects of belief and, further, of abductive inferences (Davidson, 1990). This ability is useful for complex tasks, but because it is made possible by many other skills and types of knowledge, it would be surprising if such full-blown mind reading could be deployed for on-the-fly tracking of others' beliefs without running into unbounded information-processing problems. Second, converging evidence from other paradigms suggests that even when preschoolers start to be able to make correct verbal predictions on the false-belief location test, their mind-reading ability is still limited—it takes several more years for children to develop a robust understanding that beliefs represent only some features of their referents (Apperly & Robinson, 2003). Even adults do not automatically make inferences about actors' beliefs in high-level perspective-taking tasks without being asked to do so (e.g., Qureshi, Apperly, & Samson, 2010; Surtees, Butterfill, & Apperly, 2012).

The two-systems account provides the best explanation for those findings and the findings we report here. In tracking agents' registration as a causal factor of goal-directed action, the early-developing efficient mind-reading system is generally good at what it does: In guiding eye movements, its fast, automatic, and unconscious ascriptions of "beliefs" about objects' location, contents, and properties are usually accurate. Because registration takes into account only basic relations among agents, objects, and properties, the efficient mind-reading system sacrifices flexibility, and its resulting low flexibility is revealed by signature limits. A second, flexible mind-reading system emerges at 4 years of age, when children start to integrate their mastery of complex language, their increasing general executive function skills, and their growing meta-representational knowledge to form and guide symbolic representations about belief as such (Apperly, 2011; Low, 2010; Wang et al., 2012). The advantage of the flexible system in representing relationships between agents and propositions is that it is equipped to help humans with sophisticated perspective taking in cognitively demanding situations, such as situations requiring attributions of false beliefs regarding identity, quantifiers, and ambiguous figures (Apperly & Butterfill, 2009). The two-systems account generates immediate predictions about a range of belief-related paradigms in which the efficient mind-reading system, compared with the flexible mind-reading system, will show natural blind spots in perspective taking.

In conclusion, automatic looking responses are minimally mentalistic—they reflect a system that efficiently tracks belief-like states. A dual mind-reading system combining low- and high-level processes for tracking and representing beliefs allows for much more precise predictions of how other humans will navigate the social world.

Declaration of Conflicting Interests

The authors declared that they had no conflicts of interest with respect to their authorship or the publication of this article.

Supplemental Material

Additional supporting information may be found at http://pss.sagepub.com/content/by/supplemental-data

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