Two-Systems View of Children's Theory-of-Mind Understanding

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Abstract

Theory-of-mind research reveals a puzzling pattern of young children showing implicit "mindreading" success in indirect false-belief tasks well before they can pass explicit tasks where they are asked to make direct predictions about the mistaken agent's belief or behavior. Relevant theorizing has either boosted indirect responses (e.g., eye movements) as showcasing infants' and young children's innate psychological reasoning system or scoffed at indirect responses as reflecting only a shallow causal understanding of behavior. This essay describes new theorizing suggesting that we have not one but two mindreading systems—an implicit efficient system (shared by infants, children, and adults) that supports spontaneous responses such as eye gazing and an explicit flexible system (constructed from age 4 onward) that supports direct verbal responses. This view has inspired cutting-edge research documenting signature limits on the kinds of input that the efficient mindreading system processes. New research shows that the efficient system is set to help young children and adults minimally track facts relating to agents and objects, but not relations between agents and propositions. The flexible system—supporting understanding of belief as such—guides children's direct verbal inferences in a wide range of perspective-taking situations that include ascribing how people interpret a particular object. Future research into the question of how human beings mindread in fast-moving situations will need insight into whether there are systematic patterns of limits on implicit understanding that converge across age groups, multiple paradigms, and diverse populations.

INTRODUCTION

Emma, by Jane Austin, is a celebrated novel that illustrates human beings trying to ascribe mental states to others and the perils of misinterpretations and getting people wrong. In a famous episode, a chain of comedic blunders is set up when Emma persuades her friend Harriet to refuse a marriage proposal from the kind but lowly farmer, Mr. Martin. Emma persuades Harriet to instead wait for the well-to-do vicar, Mr. Elton, to declare his affections. Emma's actions are, however, based on her false belief that Mr. Elton's tender

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attention to her painting of Harriet's portrait signifies a growing love for Harriet. It turned out that the vicar was more interested in the painting *by* Emma rather than the painting *of* Harriet. Like the characters in Austin's novel, we can infer what is on other people's minds (e.g., what people might believe, know, desire, hope, and perceive). Predicting, explaining, or changing people's behaviors on the basis of their mental states underpin many kinds of social endeavors whether it is to act altruistically, win political campaigns, negotiate business deals, communicate ideas, or plot romantic schemes.

While the study of how we can know about the mental states of others has a rich philosophical history, our everyday theory-of-mind understanding or "mindreading" as it is termed in this essay has broad significance to researchers in many fields. Among anthropologists, there is attention to how sociocultural practices can make malleable the ways by which we predict and interpret others' actions. Linguists are also interested in the extent to which attributions of mentality are tied to language users and, perhaps more fundamentally, provided by mastery of complex linguistic constructions. There is even significant interest among behavioral ecologists on whether selection pressures would favor increasingly sophisticated mindreading abilities and how one might make use of comparative methods to chart the degree to which nonhuman animals' mental representations constitute genuine thoughts and concepts. For developmental scientists, the most widely recognized reason for studying mindreading is that mental state concepts such as "belief" constitute a paradigm case of conceptual change that underscores children's active theory-like organization of observations, experiences, and data. Here, the emphasis will be on how mindreading is not foolproof—we can also misjudge where other people are coming from. The comedy of errors in Austin's novel brings into sharp focus that mindreading is cognitively demanding and might not be at work at every given situation. This essay will provide a basic overview of how the study of signature *limits* on tracking and ascribing others' actions in mental state terms can serve as a powerful tool to illuminate and differentiate the multiple cognitive systems constituting children's mindreading ability.

FOUNDATIONAL RESEARCH

A widely used measure of children's everyday mindreading ability is the false-belief task; this task captures a child's understanding that people will act in accordance with their own beliefs even when the child knows that those beliefs do not match reality. The standard task involves an unexpected transfer of an object's location to set up a perspective difference between children and the target actor. Max puts his chocolate in the drawer and goes outside to play. His mother secretly removes the chocolate from the drawer and hides it

in the cupboard. Max returns and wants the chocolate. Children are asked to verbally predict where Max will look for the chocolate: 3-year olds fail systematically answering that Max will look in the current location and 4-year olds pass predicting that Max will look in the drawer even when he is factually wrong. Rapid conceptual change between the ages of 3 and 4 years has also been found with respect to children's appreciation of the relation between their own beliefs and other people's beliefs. For example, in the unexpected contents variant of the false-belief task, children are shown a Smarties candy tube and asked what is inside the container—children typically answer "Smarties." The experimenter opens the tube to reveal that it actually contains pencils. Children are asked to predict what other people would think if shown the closed tube and told to guess its contents. Four-year olds predict that others would say "Smarties" just as they did. Three-year olds, however, report that they always knew the tube contained pencils and predict that everyone else would think that the tube contained pencils.

Decades of studies support that older preschoolers from age 4 onward show systematic success in attributing false beliefs in a variety of tasks and, further, are able to deploy their attributions for different uses or demands. Depending on cultural differences in sociolinguistic practices and child-rearing patterns, there can be subtle differences in the average age for passing false-belief tasks and contrasts in the developmental route that children might take to acquire a conception of belief. The basic age-related developmental trajectory in direct appreciation of the effect of false belief on people's actions appears to be uniform in many countries and has been replicated even among children living in preliterate hunter-gathering and agrarian communities. Given the consistency of these age-related changes in direct false-belief reasoning, one view is that there is conceptual discontinuity in the early preschool years when children's understanding of mind changes from being nonrepresentational to representational, and beliefs are appreciated as being representations about a particular state of the world.

What a child appears to understand as revealed by his or her direct verbal answers may well be different from what the child intuits as revealed by his or her indirect or spontaneous responses (e.g., eye gazing). Using the standard false-belief task, researchers have documented that when children reach 3 years of age, the location where they verbally predict Max will look for the chocolate dissociates from the location where anticipate Max will look for the chocolate: 3-year olds look first at the drawer despite answering that Max will look in the cupboard. In the absence of similar effects in much younger children, one might cautiously suggest that 3-year olds' accurate gaze responses indicate some form of implicit knowledge that is an early stage in the well-established discontinuous changes in older preschoolers' reasoning about false beliefs (Apperly, 2011). However, using a modified

nonverbal version of the standard false-belief task, researchers have found that 2-year olds also show accurate gaze anticipations that Max would search incorrectly for the hidden object. The most well-known challenge to the view of conceptual change in children's false-belief understanding, however, comes from Onishi and Baillargeon's (2005) landmark "violation of expectation" study with 15-month olds. Their idea was that if infants can represent others' false beliefs, infants should find an event that violated that concept surprising; infants should stare longer when they see an agent failing to behave in accordance with his or her false belief compared to when the agent behaves according to his or her false belief. They found that infants showed longer looking times when the agent behaved in violation of her false belief about a toy's whereabouts to search in the new location (where only infants knew the toy to be) compared to when the agent acted in accordance with her false belief to search in the old location where she last saw the toy. Onishi and Baillargeon suggested that 15-month olds already possess a representational theory of mind—infants appeal to and reason about other people's beliefs when interpreting goal-directed pursuits. Since then, researchers measuring children's indirect anticipatory or expectant gazing have suggested that 13- to 18-month olds can already attribute others' false beliefs about an object's location, type, and property. Such findings raise a startling developmental paradox: How can infants, toddlers, and young preschoolers, who consistently fail to demonstrate any mindreading ability on many variations of the standard false-belief task, appear to track others' beliefs on indirect measures?

The early mindreading account suggests that infants have an innate understanding of belief (Baillargeon, Scott, & He, 2010). Direct verbal predictions in the standard false-belief task makes great demands on general executive functioning abilities that develop more slowly compared to children's detailed innate concepts. As such, direct verbal prediction measures underestimate the depth of children's early mindreading ability. In the case of indirect nonverbal responses—as measured in violation-of-expectancy and anticipatory looking paradigms—only the belief representation process is involved and sophisticated understanding is revealed at younger ages.

A rival account is the behavior-rule account (Perner & Ruffman, 2005), which holds that indirect looking responses reflect shallow causal understanding. Infants and children are good at noticing patterns of regularities in the environment, and can statistically abstract rules that help anticipate and explain people's actions. Responses stripped to the level of eye gazing may reflect learnt (or innate) behavior rules that allow an agent's future action to be predicted from current behavior without going through the middle step of inferring the agent's mental or informational states. Thus, one alternative interpretation of Onishi and Baillargeon's study is that 15-month-old infants'

looking responses may reflect the shallow behavior rule that people will search for an object where they last saw it rather than a deep analysis in terms of people's beliefs about an object's whereabouts, which then causes them to act in the predicted way.

Strictly speaking, even older children's correct verbal predictions on the standard false-belief task (that Maxi will search in the cupboard for the chocolate) can be dominated by shallow behavior rules (people look for things where they last saw or put them). However, many researchers remain satisfied that older children can indeed reason about people's mental states. First, from about 4 years of age, individual children pass different varieties of the standard false-belief task, and also pass other problems that require general meta-representational thinking. Second, older preschoolers (especially children from about 6 years of age) use mental state vocabulary to explain and justify their predictions about others' erroneous actions in false-belief tasks (e.g., Max will look in the drawer because that is where he *thinks* the chocolate is).

Skepticism of the strong claim that children represent "belief" in their precocious indirect responses might be partly addressed if it turned out that individual infants, toddlers, and young preschoolers at least passed tests of coherence—that is, individual children's spontaneous responses were systematic across diverse perspective-taking tasks. As it stands, there is evidence of success among infants in diverse belief-inducing task contexts, but these are only between age groups and between children. Stronger evidence of individual infants and preschoolers showing systematic looking responses across false-belief tasks with different belief-inducing situations combined with different demands is hard to come by—this makes it difficult to rule out application of behavior rules when interpreting what indirect measures of mindreading actually reflect (Low & Wang, 2011). Given the computational equivalence between the early mindreading and behavior-rule accounts, any action that can be expected, anticipated, or predicted on the basis of attributing others' epistemic states can also, in principle, be based on behavior rules. There is a new theoretical solution: following Apperly and Butterfill (2009), differences between children's indirect looking responses and direct verbal responses may reflect the operation of not one psychological reasoning system but two mindreading systems (henceforth two-systems account).

CUTTING-EDGE RESEARCH

To first bring into focus the two-systems account of human mindreading, consider examples of mental state reasoning demonstrated by jury members and competitive sports players. In a court of law, a group of jury members are evaluating a defendant's belief that the money he was dealing with

was not proceeds of drug trafficking: the jury is considering whether the defendant's actions were intentional or whether he had a false belief about the nature of the cash he was accepting. The mindreading exhibited by the jury members is flexible, informed by interacting inferences about the defendant's beliefs, knowledge, desires, and intentions. Such unbounded inferences about others' reasons for action characterize a flexible and normative conceptualization of belief *as such*. Representing belief as such includes (i) negotiating complex causal structures where the agent's thoughts and knowledge cohere and combine in unbounded ways, (ii) argumentative reasoning where there is no restriction as to which evidence might be relevant to the agent's belief, and (iii) content that is propositional. Adults can engage in flexible mindreading in the specific sort of framework described previously, but such a representation of others' mental states makes great demand on language and executive resources. The cognitive demands of flexible mindreading make it less suitable for handling fast-moving social situations. Consider the reasoning exhibited by competitive sports players. A rugby player making a dummy pass quickly anticipates action without engaging in unbounded inferences about the opponent's beliefs that interfere with game playing itself; mindreading is cognitively efficient. The dual and contradictory demand of mindreading that is flexible on the one hand and efficient on the other hand motivates a two-systems proposal.

A flexible explicit mindreading system supports direct verbal reasoning; this system ascribes complex mental states to people (e.g., beliefs) and has access to one's general knowledge and store of practical wisdom. The flexible system is emergent from age 4 as language, executive function, and general meta-representational abilities develop. An efficient implicit mindreading system supports indirect looking responses; this system is shared by infants, children, and adults, but only ascribes the simple belief-like state of registration that approximates belief. An agent 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 was still there. A distinct minimal mindreading system that tracks facts about the correctness of an agent's registration is sufficient to help guide young children's spontaneous responses in certain false-belief tasks involving relations between agents and objects.

The two-systems view holds that cognitive economy in mindreading is achieved by sacrificing flexibility over representing relations between agents and propositions and makes the unique prediction that there are natural limits on the efficient mindreading system. Apperly and Butterfill (2009) suggest that one signature limit to representing registration is mistakes over identity. To make sense of this idea, consider Low and Watts' (2013) illustration of substituting coreferential names in belief reports relating to Lois Lane looking to interview Superman:

1. Lois believes that Clark Kent is in the newsroom.
2. Clark Kent is Superman.
3. Lois believes that Superman is in the newsroom.

On a belief account, the inference at step 3 is invalid; Lois thinks of Clark in a particular way and does not necessarily know Clark under the aspect of Superman. Now consider the inference in the case of registration:

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

As registration is a relation to objects and not propositions about them, the inference is valid without ascribing a belief to Lois. Someone who simply represents Lois registering <Clark, newsroom> will not understand why she would search elsewhere for Superman, for registering <Clark, newsroom> and <Superman, newsroom> are equivalent. A person who represents perspective as such will understand there are different ways of thinking about a single reference. The discovery of a natural signature limit on children's (and adults') ability to ascribe others' false beliefs about object identity—when these ascriptions are automatic or indirect spontaneous responses—makes a powerful case that more than one mindreading system is required to track and represent beliefs.

Low and Watts (2013) designed a novel task to probe for signature limits on children's (and adults') efficient ability to ascribe false beliefs about object identity. At the start of the familiarization phase of the task, participants watched two boxes lifted to reveal two toy objects of the same kind (e.g., a red boat was underneath the left-side box and a blue boat was underneath the right-side box). Both boxes were lowered and an actor entered the scene. Participants watched the actor observing each object move to occupy the opposite box (red boat moved from left- to right-side box, then blue boat moved from right- to left-side box). After lights on the windows leading to the respective boxes illuminated and a beep sounded, the actor reached through the window into the box with his preferred colored toy (e.g., blue). The remaining familiarization trials were similar except the boxes were lifted to reveal toy cars, ducks, and buggies—the actor always reached for the blue object (for half of the participants, the actor showed a preference for the red object).

After establishing to participants the actor's color preference, the test phase began. The test phase only involved a single dog-robot toy. The dog-robot toy had a face and body that was blue when viewed from one position and a face and body that was red when view from another

position. Participants watched the two boxes lifted to only show a red robot underneath the left-side box and then boxes were lowered. The actor entered and participants watched him observing the robot travel (red aspect facing participants) from the left- to right-side box. Then the robot emerged from a recessed viewing chamber inside the right-side box where it was visible only to participants and not the actor. In the viewing chamber, the robot—with its red aspect facing participants—spun 180° to reveal its blue face–body aspect on one side and spun 180° again to reveal its red aspect. Then the robot with its red aspect facing participants returned back into the right-side box. Next, participants watched the actor observing the robot—now with its blue aspect facing them and red aspect facing him—move from the right- to left-side box. Then the doors illuminated with a beep sound to indicate the actor was about to search for a blue object.

If participants are tracking and attributing others' beliefs as such, they should appreciate that there is reason for the actor to expect another dog robot (blue) to be inside the right-side box. Such an appreciation would entail an understanding of the actor's false belief about object identity. Only 6% of 3- and 4-year olds and 25% of adults correctly gazed in anticipation of where the actor believed to be a separate blue robot, while 13, 56, and 95% of the participants in those age groups provided correct verbal predictions. Aside from the object-identity-task film, all participants also watched a standard object-location-task film whereby the actor did not observe a toy being unexpectedly transferred from one location to another—there was close to ceiling correct anticipatory gazing shown by the 3-year-old, 4-year-old, and adult age groups alongside the usual developmental increase in accuracy of their verbal predictions about the actor's incorrect search action (31, 75, and 100%, respectively). In sum, all groups showed accurate eye movements when anticipating an agent's action in the location task but showed the same blind spot in spontaneously tracking *how* an agent viewed a particular object (as required in the identity task), suggesting that the quick and efficient mindreading system guiding spontaneous reasoning is limited in scope. Four-year olds and adults had no trouble making accurate verbal predictions about agents' incorrect search actions across the different tasks, suggesting that effortful verbal reasoning is supported by a distinct flexible mindreading system.

KEY ISSUES FOR FUTURE RESEARCH

There are challenges in interpreting research in limits on the efficient mindreading system. For one thing, absence of evidence is not evidence of absence, and Low and Watts' (2013) negative findings contrasts with foundational research reviewed previously on violation-of-expectancy paradigms

where infants' expectant looking is measured. For example, Scott and Baillargeon's (2009) claimed that 18-month olds are able to represent others' false beliefs about identity; their violation-of-expectancy study involved two separate objects (a nonstackable 1-piece toy penguin and a stackable 2-piece toy penguin) to measure infants' successful ability to infer an agent's false belief about which toy she was facing. However, given that there were two toys present in the test scene at all times, critics have suggested it is possible that infants may be tracking facts about types of objects present without necessarily understanding that people can interpret or identify a single object differently depending on their viewing circumstances. Low and Watts' design avoided these problems by ensuring that, for their object identity false-belief task, the spatiotemporal boundaries of the "red robot" and "blue robot" coincided so as to require children to confront *how* people with different viewing angles can interpret a single object differently.

Nonetheless, Low and Watts (2013) only showed limits on perspective-taking in one paradigm. The single-system early mindreading account could still push the explanation that a greater degree of executive function skills (e.g., inhibitory control) might have been needed to solve Low and Watts' (2013) identity task compared to their location task. Although one might be seduced to argue that preschoolers' executive control may not be sufficiently developed to inhibit inaccurate gazing on the identity task, the temptation should be resisted; such a move would not easily explain why adults with mature executive control also turned out to show inaccurate gazing on the identity task. Such an explanation also does not easily explain why 4-year olds would then apparently have sufficient executive control to give accurate verbal predictions for the identity task. Moreover, the single-system early mindreading account contends that it is direct verbal responding on false-belief tasks, not indirect spontaneous looking, that is burdened with executive function demands. Following a behavior-rule account, one could conjure up the rule "if an object is blue, agent will reach for it" to explain participants' incorrect looking to the box containing the object in the identity task. This would not explain why 4-year olds and adults did not follow such a rule when making direct verbal predictions in the identity task: They correctly predicted that the agent would reach into the empty box. Overall, the discovery of blind spots in preschoolers' spontaneous reasoning of false beliefs about object identity is consistent with Apperly and Butterfill's (2009) two-systems account predictions that the efficient system must be limited.

To help inform theoretical interpretations, one important avenue for future research is to test for converging patterns of limits on human mindreading across different paradigms and different age groups. There are allied developments involving other paradigms suggesting that the negative results for spontaneous higher level perspective-taking documented by Low and Watts

(2013) is meaningful. Apperly (2011) has examined cognitively efficient mindreading in a simple "Level-1" perspective-taking task (determining *what* items are seen by an agent) and in a complex "Level-2" perspective-taking task (determining *how* an item is seen by an agent). The clever idea from Apperly's team is that if participants automatically calculate others' perspectives, then participants should do so even when there is no need to do so in the task. In a Level-1 task, adult participants viewed a scene where an avatar stood in room with dots on the wall. Sometimes the avatar saw the same number of dots on the wall as did participants, and other times the avatar saw fewer dots (some of the dots where positioned behind the avatar that only participants could see). What was interesting was that when participants had to judge how many dots they themselves could see, participants responded more slowly and with more errors when the avatar saw a different number of dots compared to when the avatar saw the same number of dots. It seems that adults automatically track facts about what others see even when they do not need to, and even when such computations would interfere with their own responses. However, such "altercentric interference" effects did not extend to adults' (nor older school children's) handling of complex Level-2 types of perspective-taking tasks. In the latter type of task, participants faced an avatar seated at a table. The key trials showed certain digits on the table such as the number "6" where it could look like a "9" to the avatar and a "6" to participant viewers. This time there was no evidence of participants being slower or more error prone when judging how the digit appeared to them even when it appeared differently to the avatar. Experimental paradigms that provide evidence of automatic mindreading in Level-1 but not Level-2 tasks lend significant purchase to Low and Watts' findings that children's implicit understanding about false beliefs allows them to track others' "beliefs" about object location but not about object identity.

It will be worthwhile for future research to test whether individuals from a wide developmental span (say from the ages of 5 years to adulthood) systematically show accurate anticipatory looking in the object-location false-belief task and altercentric interference in the Level-1 perspective-taking task, but systematically show incorrect anticipatory looking in the object-identity false-belief task and no altercentric interference in the Level-2 perspective-taking task. Evidence of converging patterns of performance in the very same participants across multiple age groups and across very different paradigms would refine the notion that the efficient mindreading system is limited to handling certain kinds of content. Much more work also needs to be done to trace what is invariant and what changes across populations when delineating signature limits on efficient compared to flexible mindreading. The new methods for measuring indirect mindreading as developed by Low and Watts and Apperly and colleagues are suited

to gauge behavioral phenomena in Westernized and educated children and adults; they will need to be ecologically adapted for use in more diverse samples. In so doing, we would be able to conduct cross-cultural studies to chart whether signature limits on spontaneous mindreading coupled with age-related changes in direct mindreading are also found, for example, among populations that show a strong capacity for self-control very early in development (e.g., in Confucian cultures) or that focus on external powers rather than internal mental states as a means of explaining human action (e.g., divinity as a basis for intentionality in Sudanese communities of the Dinka). If converging patterns of limits were stable across individuals in very different sociocultural (and linguistic) environments, it would partly suggest that the structure of the efficient mindreading system has a high degree of genetic constraint.

As the field goes forward in mapping converging patterns of signature limits on efficient mindreading within and across age groups (using multiple paradigms and involving diverse populations), a challenging theoretical issue that is likely to emerge is whether the information provided by the efficient cognitive system intersects with the information provided by the flexible cognitive system. Following the two-systems account of mindreading outlined here, one suggestion is that while there may be some modest connection between implicit and explicit ascriptions of mental states, the exchange must be kept to a minimum to preserve the processing efficiency of tracking belief-like states in fast-moving social interactions. Low and Watts' (2013) findings support the suggestion that the efficient mindreading system is not likely to be just an implicit homolog of the flexible mindreading system as it will not be able to effectively provide candidate contents to the later-developing flexible system for a range of situations beyond its representational powers. Further experiments along such lines could inform and even revitalize related research on how a complex suite of knowledge, skills, and experiences—for example, domain general meta-representational reasoning, objective considerations of action, language, and executive functioning, social relationships, and family dynamics—partly contribute to the development and construction of a flexible system for mindreading beliefs and other complex epistemic states.

Mapping of signature limits on efficient mindreading is not a recipe for avoiding them. Limits on the efficient mindreading system might even be regarded as being adaptively beneficial, just like how egocentrism can reduce stereotype threats and improve relationship satisfaction by elevating the congruence between our own and others' opinions. A better understanding of the nature of signature limits on the efficient mindreading system can help inform when and to what extent we should take other people's points of view. Thus, it is reassuring that the cognitive trick of managing

the business of other people's minds—the dual and conflicting demands in making abductive inferences to the best explanation about others' actions in terms of mental states and how this might be accomplished in fast-moving social situations—can be achieved by invoking a combination of high- and low-level processes, which make complementary tradeoffs between flexibility and efficiency. Apperly and Butterfill's (2009) dual-process view is set to revolutionize research exploring new frontiers in the richness and complexity of children's and adults' social understanding. Vive la révolution!

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