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Infants' Theory of Mind Competency

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Abstract

Prior Theory of Mind research using elicited-response tasks in which children are asked direct questions about an agent's false belief suggests that children younger than age 4 do not attribute false beliefs to other agents. Recently, spontaneous-looking studies have claimed that soon after their first birthday, infants already reason about agents' false belief, false perception and false identity. These visual fixation researches not only provide support for the possibility of knowledge and belief attribution in infancy, but also prove that this ability is quite robust because it can be demonstrated with different spontaneous-looking tasks. The authors first examine elicited-response false belief research, which, while confirming that children under 4 years perform poorly on standard tests, suggests nevertheless that they have more implicit understanding of beliefs than they can express. We then address two recent bodies of spontaneous-looking studies that suggest that infants in the second year of life can already attribute false beliefs about location and identity as well as false perceptions. We also introduce the early psychological reasoning account for the discrepant findings of elicited-response false belief tasks and spontaneous-looking tasks. Why elicited-response tasks are particularly difficult for young children is also discussed.

Keywords: Theory of Mind, infant cognition, psychological reasoning, spontaneous-looking

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Introduction

Cognizing about mind is a normal human activity and begins at birth. People construe each other as agents undertaking intentional action based on our underlying beliefs and desires. Comprehending false belief is the clearest sign of understanding a critical aspect of the mind: its subjectivity and its susceptibility to manipulation by information (Perner & Ruffman, 2005). Acquisition of this theory of mind is one of the most impressive intellectual accomplishments of human development. When children come to understand their own and others' mind is a question that has a long history in psychology. This question is important because not only does theory of mind understanding provide evidence for a sophisticated ability to consider the information available to an agent when interpreting and predicting the agent's actions, even if this information is inaccurate and incompatible with one's own (Wimmer & Perner, 1983). But also the age at which children first attribute theory of mind signals the age at which the psychological-reasoning subsystem necessary for computing such mental states becomes operational (Baron-Cohen, 1995). Therefore, to answer this critical question, the article begins with how elicited-response studies and spontaneous-looking studies answer the question of when infants start attributing false beliefs to other agents. Next comes the implications of findings from spontaneous-looking studies for early psychological reasoning research. The article then concludes with discussion about why young children fail at elicited-response tasks but pass at spontaneous-looking tasks in infancy, as well as the inspiration to future studies on theory of mind.

For the past two decades, the central dogma in the field of children's theory of mind has come to be that children attribute beliefs to other people only when they pass the 'standard' false belief task at 4 years of age. So long as children fail this task, they lack the concept of false-belief. The 'standard' false belief task is a verbal task in which the experimenter enacts stories. The 'standard'false belief task has been used worldwide, and reveals a universal childhood theory-of-mind achievement. The first

false belief task, called the Maxi test, which was subsequently revised by Baron-Cohen, Leslie, and Frith (1985) as the Sally-Anne test or now generally termed the Unexpected Location Task or Location Change Task, was devised by Wimmer and Perner (1983). In the standard version of Maxi test, young children are shown a doll skit, in which the protagonist the Maxi left his chocolate in the location for safe-keeping. While Maxi is out of the room, his chocolate is moved to another location. Maxi returns and, at this point, the young child is asked, "Where will Maxi look for his candy?" In the standard version of the Sally-Anne test, young children are presented with a puppet, Sally, who puts her favorite candy in a basket before going out to play. In her absence, a second puppet, Anne, transfers the candy from the basket to a box. On Sally's return, the child is asked to predict where she (Sally) will look for her candy. Wimmer and Perner (1983) find that most children younger than 4 years 6 months predict incorrectly that Maxi will look in the location where the candy really is, or Sally will look in the box where they (but not Sally) know the candy is presently located. It is thought that at about 4 years of age a fundamental change from a nonrepresentational to a representational theory of mind occurs in children. Four-year-old children begin to realize that mental states such as beliefs are not direct reflections of reality, which must always be accurate, but representations, which may or may not be accurate. This developmental pattern has been confirmed with tasks testing different false beliefs (Gopnik & Astington, 1988) and with children from different countries (Liu, Wellman, Tardif, & Sabbagh, 2008). These highly consistent results have led many researchers to conclude that the ability to attribute beliefs to themselves and others does not emerge until about 4 years of age (Perner, 1991).

However, these elicited-response tasks have fairly strong demands on children's other cognitive skills－attentional, mnemonic, linguistic(Bloom & German, 2000; Carlson & Moses, 2001). Bloom and German (2000) argue that false-belief tests are too difficult for young children, and have chronicled many of these difficulties: (1) having to follow the actions of characters in a complex narrative; (2) having to realize

that Maxi could not have seen the switching of the chocolate's location; (3) having to remember where the chocolate used to be and where it is now; (4) having to appreciate the precise meaning of the question, "Where will Maxi look for his chocolate?" as opposed to "Where should Maxi look for her chocolate?" and finally, (5) having to imagine a situation which directly conflicts with current reality, thus requiring inhibitory processes that may well exceed the executive capability of children younger than 3 year olds. Therefore, subsequently, researchers then attempt to improve the potential shortcomings of the elicited-response tasks. Some researchers improve the previously noted difficulties (making the questions simpler and more specific, supplying memory aids for the story content, having the child actively participate in the transfer, making the current location of the chocolate less salient and Maxi's mistaken belief more salient), and find the performance level of 3-year-olds tends to improve (Carlson, Moses, & Hix, 1998; Freeman & Lacohee, 1995; Surian & Leslie, 1999; Wellman & Bartsch, 1988). Others even argue that because of its complexity the 'standard' FB task should simply be discarded as a task of 'theory of mind'(Bloom & German, 2000).

To address the empirical inconsistencies and theoretical controversies on theory of mind, Wellman, Cross, and Watson (2001) conduct a meta-analysis of a broad range of false-belief studies. Overall, they find that scores on standard tests significantly improved between 2.5 and 5 years of age from below-chance to above-chance levels, a trend that is independent of several factors: country of origin, type of task, nature of the protagonist, type of object, and type of question. Although 3-year-olds are aided by manipulations designed to lower some of their difficulties, average performance advanced only from below chance to chance, while the performance of older children improved beyond chance. This meta-analysis demonstrates that methodological questions have been raised about why easing the burden on inhibitory processes failed to yield above-chance performance in 2- and 3-year-olds. Taken together, these researchers suggest that comprehension of beliefs may not be fully

tapped by standard false-belief tests, and that young preschoolers may have more implicit understanding than they can express. This conjecture is consistent with revelations from recent spontaneous-looking studies using non-verbal, visual-fixation procedures with infants which suggest that knowledge and belief comprehension are present not only in 3-year-olds but also in infants.

False-belief Comprehension Prior to 2 Years

In spontaneous-looking studies, infants'understanding of an agent's mental states is inferred from behaviors they spontaneously produce as they observe a scene unfold. Spontaneous-looking tasks currently include violation-of-expectation (VOE) and anticipatory-looking (AL) tasks. VOE tasks test whether infants look reliably longer when agents act in a manner that is inconsistent, as opposed to consistent, with their false beliefs. AL tasks examine whether infants visually anticipate where an agent with a false belief about the location of an object will search for the object. To date, spontaneous-looking tasks have shown that infants can attribute to an agent a false belief about an object's location (Onishi & Baillargeon, 2005; Song, Onishi, Baillargeon, & Fisher, 2008; Southgate, Senju, & Csibra, 2007; Surian, Caldi, & Sperber, 2007), a false perception of an object (Song & Baillargeon, 2008), and a false belief about an object's identity (Scott & Baillargeon, 2009); these findings are described below.

Anticipatory-looking approach

Starting with Clements and Perner (1994), spontaneous-looking studies attempt to design a false belief task with an absolute minimum of extra cognitive demands. In Clements and Perner's study, children see a toy mouse leave its cheese at one location, then the cheese is moved when he is not looking, and children then hear the announcement that the mouse is coming back to get his cheese. The question is whether they would look to the place where the cheese really is, or rather to the old

place where the mouse falsely believes it is. Children at 2 years 11 months, seemed to anticipate that the mouse would act in accordance with his false belief. Clements and Perner (1994) then report that children show understanding of a story character's belief in their anticipatory looking responses before they show this in their answers to test questions. To prove that the anticipatory looking response provide evidence of implicit understanding of belief, Garnham and Ruffman (2001) further examine the possibility that the anticipatory looking measure is indicative of children using a seeing=knowing rule, i.e. children linking not seeing with ignorance rather than a sensitivity to belief; and find positive results with 35-month-olds. Further reinforcing this conclusion is the demonstration that most children with autism fail to show correct anticipatory eye gazes (Senju A, Southgate V, Miura Y, Matsui T, Hasegawa T, Tojo Y, Osanai H, & Csibra G., 2010). These AL studies have provided evidence that anticipatory looking may indeed reflect sensitivity to belief.

Building on prior AL results with 3-year-olds, Southgate, Senju, and Csibra (2007) showed in a non-verbal AL task that 25-month-olds can correctly anticipate where an agent with a false belief will search for an object. In the familiarization trials, a bear puppet hides a toy in one of two boxes while a female agent looks on her head is visible above a panel with two small doors, one above each box. After the bear hides the toy, the two doors light up; the agent then opens the correct door to retrieve the toy. In the test trial, the agent sees the bear hide the toy in the left or the right box. A phone then rings behind the agent, who turns toward the sound; while she is facing away, the bear retrieves the toy and leaves with it. The phone then stops ringing, the agent turns toward the boxes, and the doors light up. Most infants correctly anticipate the agent's behavior and look at the door above the box where she falsely believes the toy to be hidden. Together, these AL studies suggest that by 2 years of age, children already possess some understanding of false belief.

Violation-of-expectation approach

In VOE experiments, several studies have claimed that infants younger than 2 years may also possess some understanding of false belief (Onishi & Baillargeon, 2005; Scott & Baillargeon, 2009; Song & Baillargeon, 2008; Song, Onishi, Baillargeon, & Fisher, 2008; Surian, Caldi, & Sperber, 2007). These studies prove that infants look longer at a scene in which a protagonist searches for an object in a place she cannot know it to be (though it really is there) than to a scene in which the protagonist searches for an object where she has seen it hidden (but it no longer is).

In the pioneer VOE false belief study, Onishi and Baillargeon (2005) examine whether 15-month-olds could attribute to an agent a false belief about the location of an object. In the first familiarization trial, a toy stands between a yellow and a green box; an agent enters the apparatus, plays with the toy briefly, hides it inside the green box, and then pauses, with her hand inside the green box, until the trial ends. In the second and third familiarization trials, the agent reaches inside the green box (as though to grasp her toy) and then pauses. Next, the infants receive a belief induction trial that varies across conditions. For example, in the false-belief-green condition, the toy moves from the green to the yellow box in the agent's absence; in the false-belief-yellow condition, the toy moves to the yellow box in the agent's presence, but then returns to the green box after she leaves. Finally, during the test trial, the agent reaches inside either the yellow (yellow-box event) or the green (green-box event) box and then pauses. In each condition, the infants expect the agent to reach where she falsely believes the toy to be hidden, and they look reliably longer when she reaches to the other location instead. Thus, in the false-belief-green condition, the infants who seethe yellow-box event look reliably longer than those who see the green-box event; in the false-belief-yellow condition, this looking-pattern reversed.

Subsequently, Surian et al. (2007) provide evidence that even 13-month-olds can attribute to an agent a false belief about the location of an object, and that this agent need not be human. In the familiarization trials, a caterpillar watches an experi-

menter's hand hide an apple behind one screen and a piece of cheese behind another screen; the caterpillar always approaches the same screen to chew on the same, preferred food. In the test trial, the hand hides the two food items in the reverse locations before the caterpillar enters the scene. The infants look reliably longer when the caterpillar approaches the new location, suggesting that they expect the caterpillar to falsely assume that its preferred food is hidden in the same location as before. Furthermore, Song et al. (2008) show that 18-month-olds realize an agent's false belief about an object's location can be corrected by an appropriate communication. In one experiment, an agent hides a ball in a box and is absent when an experimenter moves it to a cup. When the agent returns, the infants expect her to search in the cup if the experimenter tells her "The ball is in the cup!", but to search in the box if the experimenter tells her "I like the cup!", indicating that they recognizes that only the first utterance could correct the agent's false belief about the ball's location.

A false perception is an erroneous conclusion, based on misleading perceptual information, about what type of object one is facing (e.g.,a grandmother or a wolf dressed in her nightclothes, in Little Red Riding Hood). Song and Baillargeon (2008) examine whether 14.5-month-olds can attribute to an agent a false perception of an object. In the familiarization trials, an agent sits behind two toys: a doll with blue pigtails and a stuffed skunk with a pink bow. Across trials, an experimenter's hands place the toys on placemats or inside shallow containers; the agent always reaches for either the doll (doll condition) or the skunk (skunk condition), suggesting that she prefers it to the other toy. In the next, box-orientation trial, the agent is absent; two large boxes with lids rest on the apparatus floor and the experimenter demonstrates that the right box's lid has a tuft of blue hair (similar to the doll's) attached to it. At the start of the test trial, the agent is again absent; the experimenter hides the doll in the plain box and the skunk in the hair box. The agent then returns, reaches for either the plain or the hair box, and then pauses. In each condition, the infants expect the agent: (1) to falsely perceive the tuft of hair as belonging to the doll, (2) to falsely

conclude that the doll is hidden in the hair box and the skunk in the plain box, and (3) to search for her preferred toy accordingly. Thus, in the doll condition, the infants expect the agent to reach for the hair box and look reliably longer when she reaches for the plain box instead; conversely, in the skunk condition, the infants expect the agent to reach for the plain box and look reliably longer when she reaches for the hair box.

A false belief about identity is an erroneous conclusion, based on misleading contextual information, about what object token one is facing. Scott and Baillargeon (2009) examine whether 18-month-olds can attribute to an agent a false belief about the identity of an object. The experiment involves two toy penguins that are identical except that one can be taken apart (2-piece penguin) and one can not (1-piece penguin). In each familiarization trial, while a female agent watches, an experimenter's hands place the 1-piece penguin and the two pieces of the disassembled 2-piece penguin on platforms or in shallow containers. The agent then places a key in the bottom piece of the 2-piece penguin and stacks the two pieces; the two penguins are then indistinguishable. During the test trials, while the agent is absent, the experimenter assembles the 2-piece penguin, covers it with a transparent cover, and then covers the 1-piece penguin with an opaque cover. The agent then enters the apparatus with her key and reaches for either the transparent or the opaque cover. The infants look reliably longer when the agent reaches for the transparent as opposed to the opaque cover, suggesting that they expect her: (1) to falsely assume that the penguin under the transparent cover is the 1-piece penguin (because the 2-piece penguin was always disassembled at the start of the familiarization trials), (2) to falsely conclude that the disassembled 2-piece penguin is under the opaque cover (because both penguins were always present in the familiarization trials), and hence (3) to reach for the opaque cover.

Summary

The evidence from spontaneous-looking studies reviewed above suggests that infants in the second year of life can already attribute false beliefs to others. This ability is quite robust: it can be demonstrated with different spontaneous-response tasks, with various belief inducing situations, and with human and non-human agents. Moreover, infants recognize that an agent can hold a false belief about an object's location because: (1) it is moved to another hiding location in the agent's absence or (2) it is hidden in the agent's absence and misleading perceptual or contextual cues cause the agent to incorrectly infer its likely location. Finally, infants can attribute to an agent a complex set of mental states that includes multiple false beliefs.

Some researchers have argued that in spontaneous-looking tasks, infants only need to notice that something is unusual; they do not need to attribute beliefs to the protagonist (Perner & Ruffman, 2005). In their commentary on Onishi and Baillargeon (2005), Perner and Ruffman (2005) wrote: "The conclusions from the standard false belief task are warranted only because understanding of false belief around 4 years of age can be demonstrated in a variety of belief-inducing situations" (p.216). These VOE false belief studies provide evidence that infants can attribute to agents not only false beliefs about location but also false beliefs about false perceptions and identity. This would help demonstrate that infants, too, succeed "in a variety of belief-inducing situations."

It is thought that children develop an understanding of false belief around 4 years of age. However, starting with Clements and Perner (1994), spontaneous-looking studies report that infants as young as 13 months have insight into whether a person acts on the basis of false belief about the world. This discrepancy touches on important issues. Why would 3-year-olds fail to provide the correct answer in a verbal false-belief test, when 13-month-old infants can correctly anticipate erroneous actions in the nonverbal false-belief test? What could account for the discrepant findings?

The spontaneous-looking results report here has critical implications for the age

at which infants become able to attribute false beliefs, false perceptions and false identities to agents, and thus for the age at which the computational subsystem responsible for attributing these internal states comes online. To better explain these implications, an account of early psychological reasoning (see also Song & Baillargeon, 2008; Song et al., 2008) and findings from neuroscience that appear consistent with this account will be presented next, and then the reason young children cannot pass the elicited-response false belief tasks will be discussed.

Early psychological reasoning account

Several researchers assume that infants have an inborn computational system for psychological reasoning that provides them with a causal framework for interpreting the intentional actions of agents (e.g., Leslie, 1994; Surian, Caldi, & Sperber, 2007). Four assumptions of the account of the psychological-reasoning system are explained next. First, the operation of the psychological-reasoning system is largely unconscious. Infants are not aware of the causal framework they use when reasoning about agents (e.g., Leslie, 2000; Song, Onishi, Baillargeon, & Fisher, 2008). Second, the psychological-reasoning system is triggered when infants attempt to make sense of the intentional actions of an agent (e.g., Luo & Baillargeon, 2005). Third, embedded in the psychological-reasoning system are a few core constraints. When pursuing a goal, agents are expected to select actions that are not only causally appropriate but also reasonably efficient (e.g., Gergely & Csibra, 2003). Finally, the psychological-reasoning system consists of at least two subsystems, Subsystem-1 (SS1) and Subsystem-2 (SS2); SS2 is assumed to come online after SS1 (e.g., Gergely & Csibra, 2003; Leslie, 1994).

With Subsystem 1 (SS1) and Subsystem 2 (SS2), children begin early in infancy to invoke a variety of internal states to make sense of agentive action. Onishi, Baillargeon, and Leslie (2007) believe that this process unfolds in two stages. The first stage allows infants to ascribe two kinds of internal states to agents: motivational

(preferences and goals) and reality-congruent informational states (what the agent knows and does not know about a scene－through perception, memory, or inference). The second stage makes it possible for infants to attribute to agents not only reality-congruent but also reality-incongruent information such as false or pretend belief. Thus, infants are now able to hold in mind two distinct versions of the same scene, one corresponding to reality (the chocolate has been moved to a new location) and the other to an agent's mistaken representation of reality (the chocolate is still in its original location). Once infants have reached the first stage and can represent someone else's knowledge or true belief, they have moved from a teleological to a mental stance; but only when they have attained the second stage and can represent another's false belief, do they possess a representational theory of mind. The spontaneous-looking studies reported here define the precise functions of SS1 and SS2. These results have explained that both SS1 and SS2 allow infants to attribute internal states (Leslie, 1994).

Subsystem-1

Subsystem 1 (SS1) allows infants to attribute two kinds of internal states to the agent, when they watch an agent act on objects in a scene: motivational and reality-congruent informational states (Premack, 1990). Motivational states specify the agent's motivation in the scene. Reality-congruent informational states specify what knowledge or accurate information the agent possesses about the scene. The agent's knowledge may come about through perception, memory, or inference. SS1 makes it possible for infants to represent both states of knowledge and ignorance. When critical information is missing from an agent's representation of a scene, so that this representation is incomplete relative to that of the infant, SS1 allows the infant (1) to identify the missing information and (2) to reason about the agent's actions accordingly (Leslie, 1994). The mechanism that is used to represent the agent's state of ignorance may be understood as a masking mechanism: By masking the information about the

scene that is not available to the agent, infants can interpret or predict the agent's actions in terms of the remaining information.

SS1 becomes operational in the first months of life and is well in place by the end of the first year. Current experiments on motivational states have revealed that even young infants can attribute dispositions and goals to agents (e.g., Luo & Baillargeon, 2005; Woodward, 1998). Experiments on reality-congruent informational states suggest that, by the end of the first year, infants (a) keep track of what objects an agent can or cannot see, and has or has not seen, in a scene and (b) use this information to interpret the agent's responses or to guide their own (e.g., Luo & Baillargeon, 2007). When SS1 is no longer sufficient to correctly predict the agent's actions, SS2's decoupling mechanism is triggered to allow the infant to specify the agent's false belief.

Subsystem-2

Specifically, subsystem 2 (SS2) extends SS1 in that it allows infants to attribute reality-incongruent informational states to agents. When an agent holds a false belief about a scene, so that the agent's representation of the scene is incompatible with that of the infant, SS2 allows the infant (1) to identify the agent's alternative beliefs about the scene and (2) to reason about the agent's actions accordingly (e.g., Onishi, Baillargeon, & Leslie, 2007). The mechanism that is used to represent an agent's false beliefs is a decoupling mechanism (e.g., Leslie, 1987). This decoupling mechanism enables infants to hold in mind two distinct versions of a scene: one that corresponds to reality and one that incorporates the agent's false beliefs but otherwise functions as expected.

Evidence from neuroscience

Recently, functional neuroimaging, neurophysiology, and brain lesion studies with normal and autistic adults have begun to identify a network of brain regions

associated with theory of mind (Saxe, Carey, & Kanwisher, 2004); these regions include the medial prefrontal cortex, the temporo-parietal junction, the superior temporal sulcus, and the temporal poles. Though neuroscientists address whether and how mentalizing is specially supported in the human brain, these neuroimaging or neurophysiological studies of theory of mind have almost never examined children. Nevertheless, these findings from neuroscience appear consistent with the two subsystems of early psychological reasoning. A recent functional magnetic resonance imaging (fMRI) experiment found significant activation differences between false- and true-belief trials, suggesting that the brain regions associated with false- and true-belief reasoning do not fully overlap (Sommer, Do¨hnel, Sodian, Meinhardt, Thoermer, & Hajak, 2007). Sommer et al. (2007) present adults with false- and true-belief stories adapted from the Sally-Ann task (Baron-Cohen, Leslie, & Frith, 1985). Each story consists of seven pictures organized in three sections. In the first four pictures (baseline section), Sally hides an object in location A while Ann watches Sally then leaves, and Ann removes the object from location A. In the next two pictures (belief induction section), Ann moves the object to location B, either before (false-belief story) or after (true-belief story) Sally returns. In the final picture (outcome section), Sally searches for the object in either location A or location B. When contrasting the belief-induction section of the false- and true-belief trials, the authors find increased activation in the right temporo-parietal junction (TPJ-R) as well as in regions of the frontal cortex including the dorsal ACC, the right dorsolateral PFC, and the right lateral anterior PFC. The TPJ-R is specifically activated during the false-belief trials, leading Sommer et al. to conclude that their results pointed to "the role of the TPJ-R in the decoupling mechanism" and more generally "in computing mental states that create a perspective difference, such as a person's false belief that contrasts with the state of reality"(p. 1383). The results of Sommer et al. (2007) suggest that the TPJ-R plays an important role in the representation of false beliefs, which is carried out by SS2's decoupling mechanism (Saxe & Wexler, 2005).

In other words, infants recruit two sets of neural processes to reason about mental states: an initial neural system (system-1) that enables them to attribute motivational states and reality-congruent informational states to the agent, but that is supplemented (system-2) to reason about the agent's false belief.

Domain-general vs. domain-specific

Researchers who adhere to two different theoretical accounts of the ontogeny of TOM remain in serious dispute about how to characterize the nature of and the acquisition of theory of mind. One group argues that development of psychological understanding depends largely on domain-general mechanisms (broad cognitive abilities such as linguistic representation, working memory, inhibitory control, etc.) while, the other maintains that it depends on inborn domain-specific mechanisms which are dedicated to reasoning about other minds. These two comprehensive accounts of theory of mind have developmental components and expectations. For domain-general account, this study predicts and receives support from findings like: (a) theory of mind understandings unfold in a progression of developmental insights, (b) theory of mind achievements are attained at different times by children with different social-communicative experiences, (c) even individuals with autism achieve some theory of mind advances, and (d) specialized brain circuitry dedicated to theory of mind reasoning is the outcome of experience-dependent development. But the importance of developmental data also holds for domain-specific positions (Scholl & Leslie 1999), that predict and receive support from findings like: (a) normal children robustly achieve theory of mind understandings, (b) and do so across all cultures and languages, (c) individuals with autism are specifically impaired in theory of mind understandings notably false belief, and (d) specialized brain circuitry dedicated to theory of mind reasoning is the cause of experience-expectant development. Although they approach the task in different ways, domain-specific and domain-general perspectives can both be described as attempting to characterize and understand complex

learning mechanisms (Scholl & Leslie 1999). Being one of the various domain-specific approaches, early psychological reasoning account gives their evolutionary perspective, and generally predicts early emergence of belief comprehension. For authors who have taken exception to domain-specific mechanisms (Bartsch & Wellman, 1995; Gopnik & Wellman, 1994), they concede that while there may well be some innate basis for theory of mind development, it is arguable whether it consists of fully formed psychological understandings or whether it rests on more limited "starting state" tendencies. Domain-general accounts believe in built-in starting states that are non-mental, but that via domain-general mechanisms produce a series of increasingly comprehensive mentalist explanations of behavior.

Regarding the domain-specific and domain-general positions, the former seems to better accord with the recent neuroimaging findings of specific brain regions dedicated to psychological reasoning (Perner, Aichorn, Kronbichler, Staffen, & Ladurner, 2007). Besides, the domain-specific account is more consistent with the emergence around 13 months of false-belief attribution, compared to the domain-general account which predicts a much slower progression from recognition of sensorimotor state to mental state. Finally, domain-general accounts are directly at odds with the findings of spontaneous-looking studies indicating that intentionality can be attributed to unfamiliar objects manifesting certain dynamic characteristics. Of the various domain-specific accounts, the early psychological reasoning account adheres closest to current findings from spontaneous-looking studies while providing a sparkling idea: infants advance developmentally from maintaining a single realistic view of events to maintaining a dual view that includes another's false beliefs about these same events. Therefore, the ability to do so implies that at that point infants have acquired a representational theory of mind.

Young Children's Failure at Elicited-response False Belief Tasks

If infants at the end of the first year of life can already attribute reality-

incongruent informational states to agents, as evidenced by their performance in spontaneous-looking tasks, then why do children across countries typically fail elicited-response false-belief tasks until about age 4? (e.g., Liu, Wellman, Tardif, & Sabbagh, 2008). Previous explanations for this well-established finding have often appealed to some form of conceptual change. For example, it has been proposed that young children lack a concept of belief (e.g., Perner, 1991) or do not yet understand that beliefs are representations rather than copies of reality (e.g., Gopnik & Wellman, 1994). However, if infants can attribute false beliefs to agents in spontaneous-looking tasks, such explanations are unlikely. For young children's failure in elicited-response false-belief tasks, the interpretation from spontaneous-looking tasks takes a different approach.

According to the account of early psychological reasoning, infants' psychological-reasoning system consists of at least two subsystems, SS1 and SS2. Most researchers agree that SS2 is likely to come online after SS1, however, exactly when it does so has been the subject of long-standing debate (e.g., Gopnik & Wellman, 1994; Leslie, 1987, 2000; Perner, 1991). Studies using elicited-response false-belief tasks suggest that SS2 is not operational until about age 4 (e.g., Callaghan et al.,2005; Liu et al., 2008; Wellman et al., 2001). In contrast, studies using spontaneous-looking false-belief tasks point to a much earlier age of onset. AL tasks have shown that 25-month-olds correctly anticipate the actions of an agent who holds a false belief about an object's location (Southgate et al., 2007), and VOE tasks have shown that 13- to 18-month-olds look reliably longer when an agent fails to act in accordance with her false perception of an object (Song & Baillargeon, 2008) or her false belief about an object's location (Onishi & Baillargeon, 2005; Song et al., 2008; Surian et al., 2007), or her false belief about an object's identity (Scott & Baillargeon, 2009). They have shown that children under 2 years old may attribute false beliefs, false perceptions and false identity to others.

Take the classic Sally-Ann task (e.g., Baron-Cohen, Leslie, & Frith, 1985) for

example. In this task, children listen to the following story acted out with props. Sally faces a basket and a box; she hides a marble in the basket and then leaves; in her absence, Ann moves the marble to the box. Children are then asked where Sally will look for her marble when she returns. Beginning at about age 4, children typically answer correctly and point to the basket; prior to age 4, children typically point to the box, the marble's current location. Success in the Sally-Ann task depends on the interaction of three separate processes. First, children must represent Sally's false belief about the marble's location; this process takes place in SS2 as children listen to the story (false-belief-representation process). Second, when asked the test question, children must pay attention to the question, decide to answer it, and tap their representation of Sally's false belief (response-selection process). Finally, children must inhibit any prepotent tendency to answer the question based on their own knowledge of the marble's current location (e.g., Leslie, German, & Polizzi, 2005). Therefore, young children's difficulty with the Sally-Ann task lies not in the false-belief representation process, as is often assumed, but rather in the response-selection and response-inhibition processes. Although children can and do represent Sally's false belief accurately, they have difficulty (1) tapping this representation when deciding how to answer the question and (2) inhibiting their tendency to respond based on their own knowledge of the marble's current location. Both these difficulties are substantial: In false-belief tasks where little or no inhibition is required (e.g., Ann takes the marble away, so that children do not know its current location), young children typically perform spontaneously (e.g., Wellman, Cross, & Watson, 2001).

This interpretation from spontaneous-looking tasks clarifies why young children succeed at spontaneous-response tasks but fail at even low-inhibition elicited-response tasks. In spontaneous-response tasks, the SS2 false-belief representation process is activated when children realize that the agent holds a false belief; the children often spontaneously reveal their understanding of this false belief in their reactions to the unfolding events. Contrary to traditional claims from elicited-response-studies, the

ability to attribute false beliefs to others is already present by the second year of life. When tested with spontaneous-looking tasks, infants attribute to agents false beliefs about location and identity as well as false perceptions. Besides, elicited-response tasks and spontaneous-looking tasks make very different demands on subjects. Elicited-response tasks require the subject to predict where the protagonist will search, whereas spontaneous-looking tasks merely require the subject to observe the protagonist's ongoing search behavior. Thus, the latter involves a low cost, spontaneous response (looking time) and the former, a more onerous response-selection process. Likewise, whereas on elicited-response tasks children must follow a complex narrative to ascertain what the protagonist knows or does not know about the location of the candy, on spontaneous-looking tasks subjects perceive directly that the protagonist has or has not seen the shift in object location. Assuming that 2- and 3-year-old children are able to represent another's false-belief, the reason for their failure to do so on standard tests might be due to three simultaneous sources of stress that overwhelm their otherwise limited processing resources: (1) having to translate from a verbal to a perceptual medium, (2) having to select the correct location, and (3) inhibiting the known real location of the candy.

Overall, the most reasonable conclusion to be drawn from the spontaneous-looking studies is that early in the second year infants come to realize that other agents have knowledge and beliefs as a consequence of experience and that some of their beliefs may be mistaken and differ from the infant's own realistic view. In thereby attributing to others representations that are false and decoupled from one's own reality the infant can be truly said to have a representational theory of mind. We consider, finally, the implications of the research reviewed above for general theories of TOM development. One fairly apparent conclusion is that the early psychological-reasoning system reviewed above is appropriate to explain the likely occurrence of belief attribution at a preverbal level. Indeed, the representational understanding demonstrated by infants appears to support Leslie's contention that improvement in per-

formance on false-belief tests between 2 and 5 years reflect performance change rather than basic conceptual advance (Scholl & Leslie, 1999). Besides, spontaneous-looking studies prove that infants comprehend the mediating role of knowledge or beliefs at 13-15 months, such comprehension actually precedes understanding of desires when verbally assessed (Bartsch & Wellman, 1995) and precedes it as well when behaviorally assessed (Repacholi & Gopnik, 1997). Further, the early psychological-reasoning account accords with the recent neuroimaging findings of specific brain regions dedicated to psychological reasoning (Saxe, Schulz, & Jiang, 2007), and is consistent with the emergence around 13 months of false-belief attribution. The early psychological-reasoning account provides a new idea that infants advance developmentally from maintaining a single realistic view of events to maintaining a dual view that includes another's false beliefs about these same events. Indeed, the ability to do so implies that at that point infants have acquired a representational theory of mind. Clearly, the shift to mentalism seems to occur earlier than previously thought.

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