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To belief or not belief: Children's theory of mind

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ABSTRACT

This paper provides a minimalist framework for understanding the development of children's theory of mind (ToM). First, I provide a critical analysis of rich interpretations of ToM tasks tapping infants' understanding of perception, goals, intentions, and false beliefs. I argue that the current consensus that infants understand mental states is premature, and instead, that excellent statistical learning skills and attention to human faces and motion enable infants' very good performance, and reflect an implicit understanding of behavior. Children subsequently develop an explicit understanding of mental states through talk from parents and siblings, their developing language abilities, and their developing distinction between self and other. The paper also examines corollary theories such as the idea that there are subsystems of a theory of mind (ToM), that infants use rules on false belief tasks, that minimalist theory is post hoc, and that parallel onset of success on different ToM tasks indicates an underlying ToM. The paper concludes by considering previous arguments against minimalist interpretations of infant performance.

Introduction

Research on infants' theory of mind (ToM) typically examines their understanding of an agent's perception, goals (e.g. desires or intentions), knowledge and false belief. False belief has been regarded as a litmus test for a representational ToM (i.e. understanding mental states as representations) because it is argued that children must recognize that one will hold a belief about the world that

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neither matches the child's own belief, nor the state of the world. In a typical false belief task, the child sees an agent place an object in a container and then leave. In the agent's absence, the object is moved to a second container and the child is asked where the agent will look for the object. Twenty years ago there was intense debate over whether children's understanding of false belief came into place at 3 or 4 years of age. The picture was further muddied when Clements and Perner (1994) showed that although 3-year-olds were incorrect when directly asked where the agent would look for the object, they nevertheless looked to the correct location (where he would think it was) when anticipating his return. They argued that children's eye gaze revealed an implicit understanding of belief (knowledge they were not aware of having) in the absence of explicit knowledge (answers to direct questions regarding where the agent would look; see also Garnham & Ruffman, 2001; Low, 2010; Ruffman, Garnham, Import, & Connolly, 2001; Wang, Low, Jing, & Qinghua, 2012).

Subsequently, Wellman, Cross, and Watson (2001) provided some clarity to the field with a meta-analysis indicating that children's performance on explicit false belief tasks improved substantially over their fourth and fifth years of life. Nevertheless, the focus has now shifted to the period of infancy. Onishi and Baillargeon (2005) argued that infants understood false belief as early as 15 months of age. In this task, infants watched while an agent saw a toy in one location, but then left before the toy was moved to a second location. Upon returning, the agent either looked in the first location for the toy or in a second location. The true belief task was identical except that the agent saw the object move from the first to the second location. In the false belief task, infants looked longer when the agent looked in the correct location than the incorrect location, whereas infants showed the reverse looking pattern in the true belief task. Onishi and Baillargeon concluded that 15-month-olds "realize that others act on the basis of their beliefs and that these beliefs are representations that may or may not mirror reality" (p. 257). These claims did not go unchallenged. Perner and Ruffman (2005) argued that infants might have reflected on behavior rather than mental states, noticing that people tend to search for objects in the location they last saw them (see also Ruffman & Perner, 2005; Sirois & Jackson, 2007). That is, whereas Onishi and Baillargeon posited that infants represented an intervening mental state (agent thinks the object is at *X*), it was possible that infants simply represented the agent's ensuing behavior having seen the object at *X*. This view is referred to as "lean" interpretation or "minimalism".

More recently, many authors have published findings indicating that even younger infants pass a variety of false belief tasks and have argued consistently and strongly that Perner and Ruffman's (2005) arguments do not apply to their findings. For instance, Baillargeon, Scott, and He (2010) concluded that, "the ability to attribute false beliefs to others is already present by the second year of life" (p. 116). Indeed, there now seems to be a general consensus that recent results demonstrate unequivocally that infants understand false belief (Carruthers, 2013; He, Bolz, & Baillargeon, 2011; Luo, 2011a; Poulin-Dubois & Chow, 2009; Scott, Baillargeon, Song, & Leslie, 2010; Song & Baillargeon, 2008; Surian & Geraci, 2012), and there are many who argue that an understanding of mental states is innate (Baron-Cohen, 1997; Legerstee, Barna, & DiAdamo, 2000; Leslie, 1987; Premack, 1990; Scott & Baillargeon, 2009), or develops in the first few months of life (Luo, 2011b; Sodian, 2011; Vaish & Woodward, 2005). Such views are frequently referred to as "rich" interpretation or "mentalism" and are consistent with the notion that infants possess certain types of "core" knowledge (Spelke & Kinzler, 2007).

The primary purpose of this paper is to (1) review recent research on infants' understanding of false belief, and to a lesser extent perception, goals and intentions, considering whether task performance necessitates an understanding of mental states as claimed, and (2) provide an alternative framework arguing that infants initially develop implicit knowledge about behavior and later explicit knowledge about mental states. Addressing each false belief study in turn is essential to avoid claims that particular studies do not have a minimalist interpretation.

In short, interpretational ambiguity arises because false belief tasks typically require infants to predict the agent's behavior based on his perception (e.g. the agent sees the object at location A and will go to A), or they measure infant looking in response to an agent's behavior (e.g. the agent sees the object at location A and goes to A or goes to B). Such tasks can be explained either by linking the agent's perception to mental states and subsequent behavior (e.g. *wants* object X, didn't see it moved, *thinks* it is at A so will search at A) or by linking the agent's perception directly to behavior without the intervening mental state (e.g. didn't see X moved so will search at A). Although Perner and Ruffman (2005) provided a similar explanation for a single false belief task, the more recent consensus is that this explanation cannot apply to subsequent findings, making a re-evaluation of recent paradigms essential.

Rather than arguing that ToM is innate, the present paper argues that there are five factors that contribute to children's learning about mental states (see Fig. 1). The first two provide initial insight into patterns of behavior:

1. There is an innate capacity for statistical learning that enables implicit learning of patterns in behavior.
2. There are innate or early developing *biases* that include interest in the eyes and face, in what people say, and in human motion. Infants are interested in human motion (Berthenthal, 1993) and discriminate biological motion by 4 days of age (Méary, Kitromilides, Mazenz, Graff, & Gentaz, 2007). Attention to motion helps infants to predict events. They observe people acting in particular ways toward objects and other persons, and they begin to understand what the person will do next. Attention to the face will help infants learn that perception (e.g. what one sees) is relevant to behavior (e.g. object search). Eventually, these biases will assist learning about mental states as well.

Three other factors then help children to develop an implicit understanding of behavior by focusing children's attention on behavior, but also, which facilitate an explicit understanding of mental states.

3. Parents frequently use mental state verbs to describe agent behavior. Understanding of mental states is initially helped (a) by conversation that focuses children on their own salient desires (assisting reflection on what it feels like to "want *X*"), and (b) when parents use a specific term (e.g. "want") to refer to different types of behavior (e.g. reaching and smiling), helping to highlight a common underlying mental state because the behaviors described are so different.

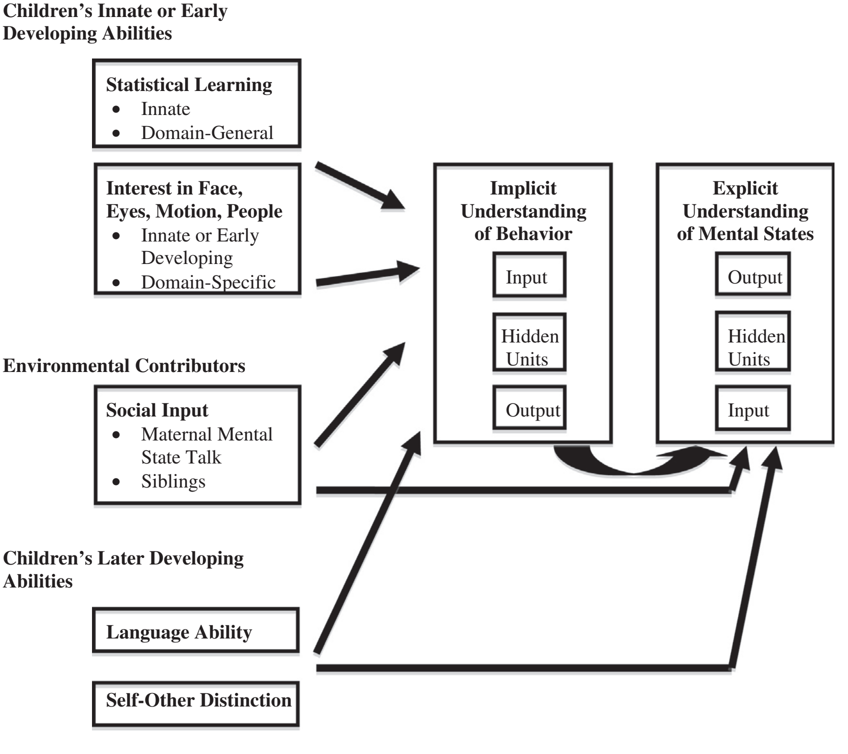

Fig. 1. From behavior to mental states.

4. Children's language evolves. This provides children with a means for understanding parent talk about mental states and for thinking explicitly about different mental states.
5. Children learn to distinguish between the self and another, enabling a better understanding of mother talk about another's mental states.

This framework is simplified in that there are undoubtedly other contributors to children's ToM, for instance, books (e.g. Adrian, Clemente, Villanueva, & Rieffe, 2005; Dyer, Shatz, & Wellman, 2000; Tsunemi et al., 2014), which are subsumed in the present framework under maternal talk (because mothers and fathers are the usual readers of books). There are also sure to be causal relations between these five contributors that are not depicted or discussed.

In describing the transition from understanding behavior to understanding mental states, I point out that the initial acquisition of knowledge about behavior likely bears some resemblance to the acquisition of implicit knowledge modeled by connectionist architectures, and that understanding behavior has obvious advantages for survival so that the ability to learn about behavior would in all likelihood be selected for in evolution. I also consider several other ideas central to the notion that infants have a ToM, including the claim that attribution of an understanding of mental states to infants is more parsimonious than attribution of an understanding of behavior, the idea that infants are using rules when reasoning about behavior, that minimalism is more post hoc than mentalism, and that there are distinct subsystems within a ToM. Finally, I consider how Spelke's (1998) arguments against Haith's (1998) minimalist account apply to the present account.

Without question, most published articles on infant ToM have argued for a relatively sophisticated understanding of mental states in infants and I think there are several reasons for this. First, we know that at some point in human development we do come to understand mental states so it seems plausible that it might be as early as infancy. Second, and perhaps most important, mentalizing is so automatic for us as adults that it can be very difficult to understand how else infants could pass a ToM task (Povinelli & Vonk, 2004). Yet, our adult view is utterly contaminated by our own skill at mentalizing and there is no guarantee that infants think like we do. Third, many have argued that mentalistic accounts of infant performance on ToM tasks are more parsimonious than accounts positing an understanding of behavior. I argue that parsimony is neither a decisive basis by which to adjudicate the two views, nor does it favor mentalistic accounts as has been argued. I begin, below, by examining a key skill that would assist learning about patterns in behavior: statistical learning.

Statistical learning and pattern recognition

Language researchers have shown that infants have an impressive ability to detect the statistical structure of patterns of stimuli. Infants less than 1 year of age can use the statistical structure of the continuous word stream to recognize that syllables that co-occur tend to form words (Johnson & Jusczyk, 2001; Saffran, Aslin, & Newport, 1996), can parse speech into linguistically relevant units, identify grammatical and non-grammatical items and match words to objects (Gogate & Bahrick, 1998; Gómez & Gerken, 1999; Johnson & Jusczyk, 2001; Mattys & Jusczyk, 2001; Morrongiello, Lasenby, & Lee, 2003). The statistical learning mechanism utilized in these tasks is domain-general in that infants can also detect structure in non-linguistic tones (Saffran, Johnson, Aslin, & Newport, 1999) and visually presented object sequences (Kirkham, Slemmer, & Johnson, 2002). Newborns also use combinations of acoustic and phonological information that occur with different probabilities to separate words into distinct categories (Shi, Werker, & Morgan, 1999), and statistical learning relates directly to verbal ability in children (Kidd, 2012). Such findings have provided evidence for how children can learn about language and an alternative to the idea that knowledge of grammar must be innate.

Learning about stimuli pairings is something that is present *at birth* and that occurs *without conscious reflection*. When *sleeping neonates* are presented with patterned strings of nonsense syllables, their brains subsequently respond differently to novel strings compared to previous strings (Teinonen, Fellman, Näätänen, Alku, & Huotilainen, 2009). Even in newborns, statistical learning is domain-general, because similar differences in brain activation are obtained when sleeping neonates are presented with patterned strings of tones (Kudo, Nonaka, Mizuno, Mizuno, & Okanoya, 2011). Likewise, when newborns are shown objects in particular sequences they dishabituate to new sequences (Bulf, Johnson, & Valenza, 2011).

Although learning of patterns can occur when infants are sleeping, it is sometimes better when infants attend to a pairing. Slater, Quinn, Brown, and Hayes (1999) presented newborn babies with a green or red line printed on white card. Each visual stimulus was paired with a word (''teat'' or ''mum''), but in one condition the word was presented only when the infant looked at the visual stimulus whereas in the other condition the visual and auditory stimuli were paired regardless of infant attention. Newborn infants' learning of arbitrary visual-auditory pairings was better when they attended to the pairing. These results are important because they provide a mechanism for preventing infants from learning *all* possible pairings of stimuli, many of which will be irrelevant, with learning enhanced for stimuli infants attend to, such as agent actions and agent–object relations, in other words, for stimuli that are central to their success on ToM tasks.

Infants use both pre- and within-experiment experience on such tasks. When anticipating the path of an object, they initially rely on prior experience (assuming a linear path), but also quickly learn new patterns of motion (a non-linear path) based on a few trials of within-experiment experience (Kochukhova & Gredebäck, 2007).

Recently, Téglás et al. (2011) showed that 12-month-olds integrate three sources of information when reasoning about object motion. Infants observed videos in which four objects bounced around inside a housing with a small opening at the bottom. At the end of the video, one object exited through the opening, with researchers examining infant looking time at these events. Videos varied according to: (a) how long the circular housing and objects were occluded prior to an object exiting (occlusion for .04, 1 or 2 s), (b) the number of objects of each type (e.g. three blue and one red), and (c) whether, prior to occlusion, the objected that exited was close to the opening or far way. Infants took each of these factors into account. When occlusion was for .04 s their looking reflected the distance an object was from the opening, when it was for 1 s looking reflected both distance and the number of objects of each type, and when it was for 2 s looking times were based only on the number of objects of each type. Importantly, infants did not have extensive prior experience with these types of displays, having watched a 19 s familiarization movie twice before watching the test movies. Furthermore, the objects had no mental states, yet infants reasoned perfectly about their movements, consistent with the idea that they needn't reflect on mental states when considering movement (i.e. an agent's reaching) in ToM tasks either.

Given that false belief tasks require infants to reason about the actions of an agent, it is important to examine infant understanding of probability in tasks with agents. Further, it seems likely that infants are innately interested in scenarios in which agents act on objects because such acts could have relevance for survival. The infant needs to learn that when someone reaches for one object over another, the neglected object might be hazardous, whereas the chosen object might be integral to survival. At least by 6 months, the youngest age examined to date, infants are aware of some typical agent–object interactions (Hunnius & Bekkering, 2010). When they see a human raise a cup they anticipate the trajectory and look to the mouth rather than another area (e.g. the ear). When they see a human raise a phone they look to the ear in anticipation that the phone will be placed on the ear.

Paulus et al. (2011) used video displays to examine 9-month-olds' ability to learn which of two paths an agent would take. Over four trials, when a cow reached a fork in a road, she disappeared behind an occluder and then always emerged on a high (rather than low) road. Infant expectations could be discerned by examining which road they looked to in anticipation of the cow re-appearing from behind the occluder, and they quickly learned to look to the high road rather than the low road.

What these studies demonstrate is that learning of contingencies is a domain-general skill present in newborns, that infants pay attention to agent actions and to agent–object relations, and that they develop knowledge and expectations about each based on frequency of occurrence. Crucially, these skills and insights would help to enable success on ToM tasks and can be seen as early manifestations of a more general tendency at all ages to ''store a continual and fine-grained record of the frequency of occurrence of events'' (Hasher & Zacks, 1984, p. 1379).

Nor is the ability to perceive patterns in stimuli unique to humans, although animals are not as good as humans. For instance, rats (Murphy, Mondragón, & Murphy, 2008; Toro & Trobalón, 2005;

Wan, Aggleton, & Brown, 1999) and apes (Rakoczy et al., 2014) demonstrate statistical learning abilities. Likewise, songbirds only respond to song if it contains at least 90% of the typical syllable order of their community (Abe & Watanabe, 2011), with knowledge of syllable order *learned*. Birds raised alone do not make these distinctions, but isolated birds can learn the syllable order in as little as two weeks.

It should come as no surprise that animals have statistical learning skills that enable them to learn about patterns because these skills will be central to their very survival. For instance, animals must be able to learn how auditory, visual and olfactory cues coalesce to indicate the probability of food, successful mating, or an attack from predators. Based on such probabilities, they must judge when a risk is worth taking and when it is not, and an animal without such ability will surely die more quickly. Thus, statistical learning is likely present in a variety of species, with humans differing only in that our capacity for statistical learning is more sophisticated than that of other species (Conway & Christiansen, 2001; Toro & Trobalón, 2005).

The upshot of this section is that pattern detection is something that can occur without effort or even conscious awareness, and that the basic ability to recognize patterns in multiple domains is present in newborn babies (also see Gopnik & Wellman, 2012). Below, I argue that statistical learning enables infants to use perception to predict behavior on false belief tasks so that I first consider perception in more detail.

The importance of perception

The minimalist account described herein holds that infants can use an agent's perception and previous behavior to reason about future behavior. However, mentalism must also hold that infants use the agent's perception (e.g. not seeing leads to a false belief) so that insight into perception is crucial for both accounts. What, then, do infants understand about perception? Infants are interested in the eyes and face. Newborns prefer to look at stimuli arranged to resemble a face than the same stimuli arranged in a non-face-like configuration (Morton & Johnson, 1991). They also look more at a face with the eyes open than eyes closed (Batki, Baron-Cohen, Wheelwright, Connellan, & Ahluwalia, 2000). By 3 months of age, some infants are also beginning to follow an adult's gaze and by 6 and 9 months, these abilities are more firmly within their grasp (De Groote, Roeyers, & Striano, 2007).

Nor is sensitivity to the eyes/head unique to humans. Many different primate species follow gaze (Burkart & Heschl, 2007; Shepherd & Platt, 2008; Tomasello, Call, & Hare, 1998), as do goats (Kaminski, Riedel, Call, & Tomasello, 2005), and even ravens (Bugnyar, Stöwe, & Heinrich, 2004; Schloegl, Kotrschal, & Bugnyar, 2007) and plovers (Ristau, 1991). For instance, ravens will look upward if a human looks upward (likely important in locating a predator) and move so that they can see behind a barrier if a human has gazed behind the barrier (likely important in locating food). Plovers will feign injury (a broken wing display) if an intruder looks toward the plover's nest but not if the intruder looks elsewhere (likely crucial to avoiding predation). Furthermore, birds are sensitive, not just to visual cues, but also to auditory cues such that if a conspecific is listening (but cannot see), scrub-jays will stash their nuts and seeds in quieter places (Stulp, Emery, Verhulst, & Clayton, 2009).

These examples illustrate that sensitivity to what is seen or heard is not a uniquely human insight. They also give pause for thought. While it might seem plausible to posit that an infant who uses eye gaze when reasoning about behavior understands seeing as a mental state (Senju, Southgate, Snape, Leonard, & Csibra, 2011), it seems more questionable to assert that birds also have such insight and more plausible that they might simply have insight into behavior. For instance, ravens and jays have learned that different caching behavior is required depending on a conspecific's potential for seeing or hearing. Plovers feign a broken wing when an intruder looks toward their nest because the intruder is otherwise likely to attack the nest. If these examples highlight the possibility that perception can be understood non-mentalistically, then they suggest that human infants might also understand perception non-mentalistically. Infants might simply observe that one who sees an object in a particular place tends to search there, one who is told an object is in a particular place tends to act in accordance with that message, etc.

Gibson's (1977) notion of "affordances" helps to elucidate this non-mentalistic alternative. For instance, several features "afford" the action of walking from a hallway into a room, such as the solidity of the floor and the width of the doorway (Greeno, 1994). In the same way, seeing or hearing can afford an agent's correct action whereas not seeing or not hearing cannot. In this view, it is not necessary to posit underlying mental states because the *action* of seeing or hearing can be linked directly to behavior. Thus, I use the terms "seeing" and "hearing" freely in the present paper without assuming they necessitate an understanding of mental experience.

In sum, I argue that infants need not have an innate understanding of mental states, although they might have an innate basis for *learning* about mental states. It seems entirely plausible that infants are innately predisposed to learn about perception and behavior (and later mental states) by virtue of their sophisticated ability to detect patterns, and their attentiveness to the eyes, face, and animate motion, and that these predispositions would be selected for in evolution because they enhance survival.

False belief

In this section, I examine whether infant false belief studies, which have been interpreted as demonstrating mental state understanding, could be explained through an understanding of behavior instead. Because researchers often argue that their study provides particularly compelling evidence for infants' ToM, omission of individual studies might lead some to conclude that the present review is not sufficiently thorough to address this question. Thus, I consider all studies examining early false belief understanding published since Onishi and Baillargeon (2005) with the exception of: (a) Kovács, Téglás, and Endress (2010), because Ruffman, Taumoepeau, and Perkins (2012) discussed this study previously, (b) Träuble, Marinovic, and Pauen (2010), Knudsen and Liszkowski (2011, 2012), Surian and Geraci (2012), and Luo (2011a), because they acknowledged infants might have passed their tasks through an understanding of behavior, and (c) He et al. (2011), because their argument that infants understand mental states is based on the implausibility of the number of behavioral rules required and I consider this idea in a separate section below.[1] In an effort to save space and avoid a tedious analysis, I address two multiple-experiment studies at length below, and then consider the rest of the studies more briefly in Table 1. The general argument is that infants use perceptual access and previous behavior to guide their understanding of subsequent behavior.

Scott and Baillargeon (2009)

In this study, an agent sat in front of a one-piece and a two-piece toy penguin (split into two halves). In Experiment 1, over repeated familiarization trials, the agent placed a key inside the two-piece penguin and then closed it so it resembled the one-piece penguin. In the false-belief condition, the agent was absent when the one- and two-piece penguins were again presented along with two boxes (one transparent and one opaque). Next, the experimenter assembled the two-piece penguin to resemble the one-piece penguin. Then, the two-piece penguin was covered with the transparent box and the one-piece penguin with the opaque box. The true-belief condition was identical except the agent saw each penguin covered.

At the conclusion of each condition, the agent grasped the lid of either the transparent or opaque box (as if about to lift the box to place the key in the penguin inside) and infant looking time at each event was measured. In the false-belief condition, 18-month-olds looked longer when the agent

[1] One other recent study was conducted by Yott and Poulin-Dubois (2012). They tested whether 18-month-olds' learning of a rule might affect their reasoning on a false belief task by teaching children over eight trials that an object placed in one container re-appeared in a different container. They then examined whether this new rule learning affected children's reasoning on a false belief task. Yott and Poulin-Dubois found that it did not, which they suggest is inconsistent with the idea that infants use rules on false belief tasks. However, even Yott and Poulin-Dubois point out that there were many shortcomings in this experiment: (1) learning over eight trials is not likely to over-rule *18 months* of contrary experience, (2) infants could have learned the object always appears on one side or in a blue container rather than learning a more generalized rule that the object appears in the opposite container to where it was hidden, (3) the experimenter violated the rule in the last training trial by searching where the object was, and (4) there was no reason to transfer from the training phase to the test phase because training and test employed different agents, took place in different rooms, and used different materials. For all of these reasons, this experiment does not provide any insight into whether infants use rules on false belief tasks.

Table 1
Summary of false belief studies.

Study type	Finding	Explanation
Anticipatory looking		
Southgate et al. (2007): 25-month-olds	*TB*: Look to actual location when anticipating agent's search *FB*: look to initial location when anticipating agent's search	Infant recognizes what agent sees and doesn't see, and that people search for objects where they last saw them ⇒ expects agent to search for object at initial location only when hasn't seen object removed
Senju et al. (2011): 18-month-olds	Agent sees object in one of two boxes *Opaque blindfold*: Agent wears opaque blindfold, doesn't see object removed ⇒ anticipate agent searching at initial location for object *Transparent blindfold*: Agent wears transparent blindfold, sees object removed ⇒ *don't* anticipate agent searching at initial location	Infant recognizes what agent sees and doesn't see, and that people search for objects where they last saw them ⇒ expects agent to search for object at original location only when hasn't seen object removed
He et al. (2012): 30-month-olds	Agent sees scissors in one of two containers *TB*: Agent watches experimenter place scissors in her pocket *FB*: Agent doesn't see this *Experimenter prompt*: Looking at ceiling, "But when (agent's name) comes back, she's going to need her scissors again . . . Where will she think they are?" ⇒ children tended to look correctly *Experimenter direct question*: Looking at child, "But when (agent's name) comes back she's going to need her scissors again . . . Where will she think they are?" ⇒ children tended to answer *in*correctly	Prompt is an indirect measure (experimenter looking at ceiling) ⇒ indirect measures likely to tap implicit knowledge (Berry & Dienes, 1993; Garnham & Ruffman, 2001; Low, 2010; Ruffman, Garnham, Import, et al., 2001; Wang et al., 2012) ⇒ direct question taps explicit knowledge ⇒ implicit knowledge precedes explicit knowledge ⇒ eye gaze reflects implicit knowledge of agent behavior (Ruffman et al., 2012)
Violation of expectation		
Surian et al. (2007): 13-month-olds	*Training*: Agent (caterpillar) goes to one object (e.g. apple), not another (cheese), four times *TB*: Infant looks longer when agent sees where objects placed, and then goes to previously ignored object (cheese) rather than apple *FB*: No significant difference in looking when agent doesn't see where objects placed and goes to apple or cheese	Agent's repeated behavior in training phase is to go to apple ⇒ infants expect agent will go to apple again if sees where apple placed ⇒ longer looking when agent sees where apple placed but goes to cheese instead (new agent–object relation must be encoded)
Song et al. (2008): 18-month-olds	Agent sees ball in one container, goes away, ball moved to second container (cup) *Agent receives informative message*: "The ball is in the cup"/Point to cup ⇒ infants look longer when agent fails to use message and looks in *in*correct location *Agent receives uninformative message*: "I like the cup"/No point to cup ⇒ infants look longer when agent looks in correct location	Pointing and an informative verbal message provide perceptual information as to an object's location ⇒ 18-month-olds are known to use pointing to direct behavior and help an adult find a toy (Knudsen & Liszkowski, 2011, 2012) ⇒ infants use verbal messages and pointing as indicating object location for themselves and expect others to do likewise
Song and Baillargeon (2008): 14.5-month-olds	*Familiarization*: Toy skunk on one mat, doll with blue pigtails on other ⇒ agent reaches for doll four times	*Familiarization*: Agent reaches repeatedly for doll/blue hair ⇒ infant assumes doll or *aspects* of doll (e.g. blue hair) cause search ⇒ in real life people do reach for objects (e.g. newspaper covered by other items) when only a *small portion* is visible
	Test: Agent sees or doesn't see skunk and doll placed in opaque boxes ⇒ skunk in "hair" box (blue pigtail hanging from lid), doll in plain box ⇒ agent reaches for hair box or plain box ⇒ infants looked longer when (a) ignorant agent reaches for plain box rather than hair box, and (b) knowledgeable agent reaches for hair box rather than plain box	*Agent sees where doll placed*: Perceptual information = seeing doll placed in plain box ⇒ consistent with familiarization, agent should reach for doll/blue hair in plain box where she has seen it *Agent doesn't see where doll placed*: The only perceptual information is seeing blue hair ⇒ no perceptual information relates the agent to the plain box, but is a reason for agent to reach for

Table 1 (*continued*)

Study type	Finding	Explanation
		hair box because she reached for hair in familiarization
Poulin-Dubois and Chow (2009): 16-month-olds	*Reliable agent*: Looks in container, says "Wow", four times ⇒ container revealed to contain object *Unreliable agent*: As above but container empty *TB*: Agent sees object in one of two containers, reaches for that container or empty container ⇒ infants looked longer when reliable agent reached for empty container than full container ⇒ no difference in looking when unreliable agent reached for empty or full container	Used a TB task but only <u>*FB*</u> potentially provides evidence of belief insight. Infant reasons about behavior: (a) predictable agent enthuses when container full ⇒ this behavior matches life experience and is predictable ⇒ expect reliable agent will go to full container, (b) unpredictable agent enthuses when container empty ⇒ this behavior breaks conventions, is not predictable ⇒ no clear prediction for approaching full/empty containers
Helping behavior		
Buttelmann et al. (2009): 30-month-olds	Agent sees object in one of two containers	*FB*: Infant sees agent searching where last saw object ⇒ in everyday experience, infant observes that search behavior typically ceases when object retrieved ⇒ infant assumes this search is similar ⇒ because agent has not obtained object, infant retrieves from 2nd container
	FB: Agent leaves before object transferred to second container *TB*: Agent sees transfer from first to second container *Both conditions*: Agent returns, tries but can't open 1st container, asks infant to "help" ⇒ infant opens 1st container in TB, second container in FB	*TB*: Agent had seen object in 2nd container but searches in 1st container ⇒ infant recognizes this search can't be about retrieving the object ⇒ infant opens 1st container
Southgate, Chavalier, and Csibra (2010): 17-month-olds	Agent places two novel, unnamed objects in separate boxes and leaves *TB*: Agent returns, sees each object switched from one box to the other ⇒ agent points to a box, says he had placed a "sefo" in there, "Shall we play with the sefo?" ⇒ child chooses item in referred-to box *FB*: As above except agent does not see switch ⇒ child chooses item in box not referred to	In each task, agent points to a box and says, "Do you remember what I put in here? There's a sefo in here" ⇒ infant remembers which object agent had seen in the referred-to box, labels that a "sefo", and then retrieves this object ⇒ in TB, the object the agent had seen in the referred-to box is still there so the infant retrieves that object ⇒ in FB, the object the agent had seen in the referred-to box is *now in the other box* so the infant retrieves that object

Note. TB = True belief: agent sees where object(s) placed, FB = False belief: agent doesn't see where object(s) placed.

grasped the handle of the transparent box, looking as though the agent was about to grasp the one-piece penguin (although in reality it was the two-piece penguin). In the true-belief condition (when the agent had seen the two-piece penguin covered with the transparent box), infants looked longer when the agent grasped the handle of the opaque box. Scott and Baillargeon (2009) claimed that this pattern of looking demonstrated that infants knew the agent had a *goal* of hiding her key and *falsely believed* the two-piece penguin was inside the opaque box in the false-belief condition.

Nevertheless, a similar looking pattern would be obtained if infants just think about behavior. In the true-belief condition, infants had seen the agent reach repeatedly for the two-piece penguin in the familiarization phase, and that the agent saw the two-piece penguin covered with the transparent cover in the test phase. It would therefore be very strange were the agent to reach anywhere else but for the transparent cover. In the false belief task, the agent did not see where each object was placed in the test phase so this does not inform the infant's expectation. However, in the familiarization phase the infant had only ever seen the agent reach toward a penguin broken into two pieces, and had never seen the agent reach for, or place a key inside, an *intact* penguin. Thus, when the agent reaches toward an intact penguin, the infant looks for longer because a new agent–object relation must be encoded. In contrast, when the agent grasped the lid of the opaque container in the false-belief condition, this was a new action, but (a) did not violate the behavior observed in the familiarization phase (because an opaque box was never present), and (b) was at least partially consistent with the behavior in familiarization trials in which the agent also reached *away from the intact penguin*. This explanation makes sense of the pattern of infant looking time but is based solely on the agent's failure to see where each object was hidden, and the degree of similarity between the agent's behavior in the familiarization phase (reach away from intact penguin) and test phase (reach toward intact penguin) rather than the agent's false belief.

Experiment 2 included a no-key condition similar to the false-belief condition except that in the familiarization phase the agent did not have a key and therefore did not place a key inside the two-piece penguin. Instead, the agent simply reached away from the one-piece penguin in order to put the two-piece penguin together. In the test phase, there was again no key and no apparent desire to place a key inside the two-piece penguin, and the agent placed her hand on the lid of either the transparent box (that contained the two-piece penguin, but which was put together to resemble the one-piece penguin) or the opaque box. In this case, infants did *not* look longer whether the agent placed her hand on the lid of the opaque or the transparent box, leading Scott and Baillargeon (2009) to conclude that without a goal (to place a key inside the two-piece penguin) infants had no expectation that the agent would search for the two-piece penguin.

Yet, an alternative explanation is that the agent's behavior in the familiarization phase – reaching to the two-piece penguin – is given a more elaborate context in Experiment 1 when she places *a key* inside the two-piece penguin, and is therefore more memorable. An elaborated context is generally recognized as an aid to memory (e.g. Pressley, 1982). That is, in both the "Key" (Experiment 1) and "No Key" (Experiment 2) conditions, the agent puts together the two-piece penguin, but in the "Key" condition of Experiment 1 the agent also places a key inside. There are, therefore, two events to enrich the context and enhance memory for the agent's actions in the "Key" condition of Experiment 1. Infants' improved encoding of the agent's actions in the "Key" condition would subsequently result in their increased looking at a discrepant event (reaching to the intact penguin) in the "Key" condition of Experiment 1 relative to the "No Key" condition of Experiment 2. Again, infants can pass the task using perceptual/behavioral cues without inferring mental states.

Scott et al. (2010)

In the familiarization trial of Experiment 1, 18-month-old infants watched while the experimenter shook a red cup with silver stars, creating a rattling sound. She then shook two other cups by the agent's window, an identical red cup and a green cup, with only the green cup producing rattling. An agent either saw this (knowledge condition) or did not see (false belief condition). In the test trials, the experimenter again produced a rattling noise by shaking her red cup and then asked the agent, "Can you do it?" Of the two cups by the agent's window, the agent either chose the identical red cup or the green cup. Infants showed the correct looking pattern, looking longer when the agent chose the red cup compared to the green cup in the knowledge condition, but doing the opposite in the false belief condition.

Experiment 2 also included a false belief and a knowledge condition. In both conditions, there was an initial familiarization trial, as above, in which the experimenter demonstrated to the infant and agent that her red cup rattled, but of the two cups by the agent's window, only the green one rattled but not the red one. In the false belief condition the infant (but not the agent) then watched while the experimenter removed the lids from the two cups and poured marbles from the green cup into the red cup, and then replaced the lids (so that the red cup would now rattle). In the knowledge condition, both the infant and agent saw this transfer. The test trials were identical to those of Experiment 1. Once again, infants showed the correct looking pattern, looking longer when the agent chose the red cup than the green cup in the false belief condition, with the reverse looking pattern in the knowledge condition.

Experiment 3 included an ignorance condition in which all three cups were red. In the familiarization trial, infants (but not the agent) watched the experimenter shake all three cups in turn, with the experimenter's cup rattling, and of the two cups by the agent's window, only the right-hand cup rattling. In the test trial, the experimenter shook her cup to demonstrate rattling and asked the agent, "Can you do it?" The agent then selected either the left-hand or the right-hand cup, and infants' looking time to each event was examined. In this case there was no clear reason to expect the agent to select either cup, and as expected, infants' looking time at each event was about the same.

Scott et al. (2010) argue that "(t)hese results suggest that 18-month-olds can attribute false beliefs about non-obvious properties to others" (p. 366), yet the results are also perfectly consistent with a behavioral interpretation. Infants tend to imitate the actions of others. If 14-month-olds witness an adult illuminating a light bulb by pressing his forehead to it, they tend to do likewise rather than using their hands (Meltzoff, 1988). It is reasonable to assume that infants expect others to also imitate so that infants will expect the agent to copy actions so far as is possible given the agent's perceptual access. In the present study, two behaviors were relevant – which cup the experimenter shakes (green or red) and the rattling sound it produces. Given that the experimenter *shakes* her cup (rather than simply holds it), and the cup produces a distinctive rattling noise, shaking and rattling are likely to be more salient than choosing a same-colored cup, so that the infant will expect shaking and rattling to be reproduced.

In Experiment 1, in the test trial of the false belief condition, the experimenter shakes her red cup and it rattles. In this case, the agent didn't see which of the two cups by her window produces rattling. The only thing the agent has to go on is what she has just seen the experimenter do – rattle the red cup. If infants reason about perceptions and behavior, they will expect the agent to choose the red cup because she has just seen a red cup rattling. In the test trial of the knowledge condition, the experimenter again shakes her red cup. However, in this case, the agent has additional perceptual information. She has just seen that, of the two cups by her window, only the green cup rattles. If the agent is expected to imitate the salient action of rattling, and the agent has seen that the green cup in front of her rattles, then the agent's additional perception in this condition means that the infant should expect her to select the green cup. In each case, the agent acts on the basis of what she has seen and the infant doesn't need to infer beliefs.

In Experiment 2, a similar explanation applies. When the agent has seen that the green cup rattles and hasn't seen the marbles switched to the red cup, the agent's behavior will be consistent with her perception and she will choose the green cup. In contrast, if the agent sees the marbles transferred to the red cup then she should choose this cup because this cup will rattle. In Experiment 3, when all three cups are identical and the agent has not seen which of the two cups by her window rattles, there are no grounds for choosing one over the other so that infant looking time is equal whether the agent chooses the correct or incorrect cup. In all three experiments, infant looking can be explained if they reason about what the agent has seen and her subsequent behavior without inferring goals or beliefs.

Parsimony

A recurring argument is that it is more parsimonious to argue that infants understand mental states than to argue they understand only behavior (Buttelmann, Carpenter, & Tomasello, 2009; Carruthers, 2013; He, Bolz, & Baillargeon, 2012; He et al., 2011; Onishi & Baillargeon, 2005; Song & Baillargeon, 2008; Song, Onishi, Baillargeon, & Fisher, 2008; Southgate, Senju, & Csibra, 2007; Surian, Caldi, & Sperber, 2007; Surian & Geraci, 2012. For instance, Song and Baillargeon argue that a rule-based account of such findings is "increasingly far-fetched" because there are too many rules needed to result in an understanding of how the protagonist will act, that infants could not have formed these rules previously, and that it is more parsimonious to assume infants understand beliefs (p. 311). Song and Baillargeon claim that the behavior account requires that infants learn rules such as people will search in a particular location for an object if they see it disappear in one place but do not see it moved, do not get an informative message, do not get an informative point, see a small portion of the object at a different location, etc. In sum, there is a widespread belief that mentalist theory is more parsimonious than a minimalist account.

Although Povinelli and Vonk (2004) carefully considered the issue of parsimony when examining whether primates had a ToM and Perner (2010) re-visited the issue of parsimony, many researchers continue to argue that the ToM account is more parsimonious. Thus, I address this issue again here. Crucially, mentalism necessitates that infants understand how and when a false belief will be formed, and these causal conditions are the same conditions necessary for understanding an agent's behavior. One must recognize that a false belief will ensue if the agent sees an object placed in one location but doesn't see it moved, gets a misleading message, etc. An understanding that someone holds a false belief cannot simply appear out of thin air; it must be rooted in an understanding of the conditions that led to the belief or infants could not differentiate between varied contexts and would ascribe false beliefs even in situations in which a true belief was appropriate. Therefore, both the mentalist and minimalist accounts require infants to understand the importance of the same set of perceptual conditions, either as causes of behavior or beliefs.

Yet, this is not something that researchers arguing for mental state understanding in infants typically acknowledge. For instance, He et al. (2011) claim that "as more and more belief-inducing situations are examined, more and more behavioral rules must be posited to explain positive results, and the claim that infants and toddlers come to the laboratory equipped with the same extensive list of ordered rules becomes less and less plausible" (p. 302). Likewise, Surian et al. (2007) argued that, "evidence of where people last saw an object is not easily tracked in everyday experience" (p. 585). These claims are entirely self-defeating because if infants really do understand false belief, then they must also understand how the exact same perceptual conditions are causes of beliefs (rather than behavior). If they can't do this, then they can't differentiate true and false beliefs.

However, even if infants did understand that certain conditions lead to false beliefs, this still wouldn't allow a correct prediction of behavior unless they also understood that one who holds a false belief (i.e. that an object is at location A) will search at that location for the object. Thus, a mentalist account is actually *less* parsimonious, not more parsimonious, because there is an extra step in computing the action that follows from a false belief in addition to understanding the conditions that give rise to the belief. In sum, the main argument raised by those believing in mentalism – parsimony – does not stand up when examined closely.

Low and Wang (2011) extended the argument for parsimony, arguing that it ceases to be an advantage for minimalist accounts if an individual child passes different questions on different false belief tasks. For instance, consider the case in which a child passes three tasks: an unexpected transfer task (object moved in agent's absence), a misinformation task (agent told object is in *X* when it is really in *Y*), and an unexpected contents task (crayons box with candles inside). Furthermore, for each task the child correctly states where the agent will look for an object, where the agent will say the object is, and where an agent will point to locate an object. Low and Wang argue that minimalism needs nine rules to permit success in all cases whereas mentalism requires only six ToM rules (see Table 2).

Yet, this assessment does not allow for any generalization on the part of the infant. If infants recognize that one who says an object is in *X* also tends to point to *X* and to look for the object in *X*, then the nine rules attributed to minimalism could be reduced to four, and suddenly the minimalist view is again more parsimonious (see Table 2). The simple fact is that it is unknown what generalizations infants make and, therefore, which view is more parsimonious, and further, that parsimony is not a necessarily correct means for deciding between the two views (Apperly & Butterfill, 2009; Low & Wang, 2011), and for this reason should not be continually resurrected as the killer blow for either view over the other.

There are other purported advantages of mentalism related to parsimony. For instance, mentalism is said to be predictive whereas minimalism is post hoc, generating rules after-the-fact to explain infant performance (Carruthers, 2013; Knudsen & Liszkowski, 2011; Surian & Geraci, 2012). Yet, this is simply misleading. If infants use prior and within-experiment experience to reason about behavior, then minimalism reliably predicts that they will succeed on a task when they have knowledge of the agent's perception and grounds for predicting behavior. Thus, both minimalist and mentalist theory are predictive, and minimalism only *appears* post hoc because of our automatic tendency as adults to compute the mental states underlying behavior. Because this process is automatic, it is necessary for an adult to think again and imagine how else an infant could pass a task. The idea that minimalism is post hoc is therefore true when describing an adult human's thinking about a belief task, but potentially misleading when applied to infants because it reflects an adult's egocentric application of their own framework for understanding the world to another being, in other words, a *failure of the adult's own ToM*. To the extent that an adult's automatic tendency to mentalize can be suspended, it becomes more obvious that success on belief tasks can ensue through reasoning about perceptions and behavioral patterns.

Others claim that infants are innately endowed with a theory of mind module that matures with age (Leslie, 2005). Superficially, this might appear more parsimonious than saying that infants must

Table 2
Parsimony in predicting beliefs.

Minimalism	Mentalism
Low and Wang (2011)	Low and Wang (2011)
1. Agent will look where she last saw *X*	1. If agent saw object in *X*, will falsely believe object in *X*
2. Agent will say *X* is where she last saw it	2. If agent told object in *X*, will falsely believe object in *X*
3. Agent will point to where she last saw *X*	3. If agent sees container *X*, will falsely believe container contains *X*
4. Agent will look where she was told *X* was	4. If agent falsely believes object in *X*, agent will look for object in *X*
5. Agent will say *X* is where she was told it was	5. If agent falsely believes object in *X*, agent will say object is in *X*
6. Agent will point to where she was told *X* was	6. If agent false believes object in *X*, agent will point to *X*
7. Agent will look for *X* in container that usually contains *X*	
8. Agent will say *X* if container usually contains *X*	
9. Agent will point to container if it usually contains *X*	
Present account	Present account
1. Agents who look in *X* for an object also tend to say/point to *X*	1. Agents who look in *X* for an object also tend to say/point to *X* (as above)
2. Agent will look/say/point to *X* when she sees object at *X*	2. Agent will falsely believe object in *X* if sees object in *X*
3. Agent will look/say/point to *X* when she is told object is at *X*	3. Agent will falsely believe object in *X* if told object in *X*
4. Agent will look/say/point to *X* when container usually contains *X*	4. Agent will falsely believe *X* inside if sees container *X*
	5. Agents who false believe object in *X* will look/say/point to *X*

learn about mental states. However, even if certain brain areas are innately predisposed to *process information* about mental states, this does not mean that *knowledge* is innate. For instance, the fusiform gyrus becomes specialized for processing faces, but also cars in car enthusiasts, yet one wouldn't want to say that knowledge of cars is innate (Ruffman & Perner, 2005). The idea that minimalism is onerous also fails to acknowledge what infants can do, including detecting patterns, monitoring eye gaze, anticipating human actions, and learning very rapidly. A newborn learns a face prototype (an average face) in less than 1 min having seen just four exemplars (Walton & Bower, 1993). It, therefore, seems plausible that an infant could learn enough about behavior to pass a false belief task in the first few months of life. Indeed, the earliest age at which infants pass a false belief task is 7 months (Kovács et al., 2010). By this time an infant has had not 1 min, but about *100,000 min* of waking time in which to learn about events (Haith, 1998), more than enough to learn about patterns of behavior.

Further, if a ToM is innate, then either knowledge of the ways in which perception causes beliefs must also be innate or it must be learned (and once again, must be learned in the first few months of life). It certainly does *not* seem more parsimonious to say that infants are born with knowledge of the conditions that give rise to beliefs because then one has to explain how such knowledge would be encoded in genes. Alternatively, if the nativist claim is that infants learn about the conditions that give rise to beliefs, this does not seem more parsimonious than minimalism either. That is, minimalism must hold that infants learn crucial information in the first few months of life (e.g. agent sees/hears/touches object at A ⇒ agent will search at A), but mentalism would have to make similar claims (e.g. agent sees/hears/touches object at A ⇒ agent believes object at A ⇒ agent will search at A). Thus, the purported advantage of mentalism once again disappears.

False belief summary

Each of the experiments examining infants' understanding of false belief has both a mentalist interpretation and an interpretation positing that infants understand behavior. The typical argument is that mentalist theory is more parsimonious or plausible, yet this is not true. At some point, children do understand mental states but the tasks described above do not provide convincing demonstrations of this insight. In the next section I provide a brief examination of other tasks claimed to demonstrate that infants understand mental states.

Goals and subsystems

Researchers examining false belief understanding in infancy often include a list of other mental state insights – goals, intentions, knowledge and perception – that infants are said to have. Some argue that there are two subsystems comprising ToM, both of which allow infants to attribute internal states to an agent (e.g. Scott & Baillargeon, 2009). Subsystem-1 is said to be present in the first few months of life and well in place by the end of the first year. It allows infants to attribute motivational states (e.g. goals) and reality-congruent informational states (e.g. whether an agent can see an object and how this guides the agent's response). Subsystem-2 is said to allow infants to attribute reality-incongruent states to agents and to come online when infants show insight into false belief. Song and Baillargeon (2008) claimed that this was 13 months of age based on Surian et al. (2007), although they would presumably re-adjust the onset to 7 months given the Kovács et al. (2010) study.

One could ask why there are two subsystems and not, say, three. For instance, why are motivational states and reality-congruent states lumped together into a single subsystem given that they assume insight into different aspects of ToM: goals/desires/intentions versus what one can or can't see. In addition, success on each kind of task seems to come at a different age. Tasks designed to examine goals are passed by infants as young as 3 months of age (Luo, 2011b), whereas tasks designed to examine information states elicit uneven performance, with some passed around 6 months and others failed even at 18 months (see below). It simply does not make sense to conceive of these two tasks as part of the same subsystem when they tap different insights and are passed many months apart, particularly considering that a task purported to measure subsystem-2 is passed at 7 months, an age between these two tasks.

A deeper concern is whether the subsystem-1 tasks actually measure mental insights as purported. For instance, some of the authors cited by Song and Baillargeon as providing evidence for goal understanding are, in fact, more circumspect themselves. For instance, Sootsman Buresh and Woodward (2007) claim, "(i)t is an open question whether infants understand individual goals as mental states" (p. 310), Csibra (2008) interprets his findings into "goal prediction" as evidence for a teleological bias in infants, that is, that infants predict the *end point of an action* rather than the mental state that might underlie that action, and a methodological artifact has been purported to explain infant performance on the helper/hinderer paradigm of Hamlin and colleagues (Scarf, Imuta, Colombo, & Hayne, 2012a, 2012b).

In general, tasks designed to measure an understanding of goals and informational states can as readily be construed as tapping an understanding of behavior. The infant uses a combination of their pre-experimental experience of actions in the world and their observations in the experimental familiarization phase in which they observe a pairing between an agent and an object. In the test phase, that pairing is either repeated or a new pairing is introduced, with a new pairing eliciting longer looking time because it requires additional processing. Likewise, tasks meant to measure gaze following and intention understanding (e.g. Bellagamba & Tomasello, 1999; Carpenter, Call, & Tomasello, 2005; Meltzoff, 1995) also have straightforward behavioral interpretations, which are described below, in Table 3, and in Ruffman et al. (2012).

Meltzoff and Brooks (2008) found that 18-month-olds who had worn a transparent blindfold were more likely to follow the gaze of a blindfolded agent, compared to infants who had worn an opaque blindfold. Senju et al. (2011) argued that children's experience with the blindfolds helped them to understand what the agent could or could not see, and that "even the leanest interpretation of such extrapolation from the first to the third person entails the understanding of the unobservable mental state of seeing" (p. 880). This argument seems to follow from the intuition that experience with the transparent blindfold permits insight into one's own visual experience, which then assists understanding of another's mental experience, yet this claim seems unnecessarily rich. Consider, for instance, the child's knowledge of how to capture an adult's attention. A child might regularly use devices such as eye contact, excited vocalizations, and laughing to capture attention, yet have no awareness of doing so, insight into why these devices work, nor have a mentalistic understanding

Table 3
Summary of goal/intention studies.[a]

Study type	Finding	Explanation
Goals		
Woodward (1998), Woodward and Guajardo (2002), Biro and Leslie (2007), Luo (2011a, (2011b) ⇒ 3-month-olds and up	*Familiarization*: (a) Agent reaches for (goes to) object X repeatedly (not Y), (b) Agent touches X repeatedly with back of hand, (c) Mechanical claw reaches for X repeatedly	*Agent reaching*: Infants use combination of pre-experimental and familiarization experience to predict action ⇒ expect agent who has reached repeatedly for A (gone to A) to reach for A again ⇒ replicates what see in real life (agent reaches for cup repeatedly but leaves other objects on table untouched) ⇒ readily integrated into established framework for understanding action (e.g. agent will pick up object and do something with it)
	Test: (a) Agent reaches for (goes to) object Y, (b) Agent touches Y with back of hand, (c) Claw reaches for Y *Finding*: Infant looks for longer in (a), but not (b) and (c)	*Back of hand/claw*: Infants have no prior experience with back-of-hand gestures or mechanical claw and no rich framework in which to integrate these gestures ⇒ less reason to expect to happen again
Intentions		
Meltzoff (1995), Carpenter et al. (1998), Olineck and Poulin-Dubois (2005), Brandone and Wellman (2009): 10-month-olds and up	*Familiarization*: Agent tries unsuccessfully to complete an action (e.g. pull a small dumbbell apart) *Finding*: Infant completes action (pulls dumbbell apart). The claim is that infants have recognized the agent's intention (to pull dumbbell apart)	(a) Infants imitate the action ⇒ pull outward on dumbbell ⇒ inevitable outcome is dumbbell pulled apart (b) Infants see the agent's action and predict the outcome ⇒ force applied laterally will pull dumbbell apart ⇒ then use this idea to pull dumbbell apart ⇒ haven't "read" intention, have formed idea independently based on agent's actions
Bellagamba and Tomasello (1999): 18-month-olds	*Finding*: Infants do not produce end state if not shown how to produce end state and just shown object in end state. The claim is that infants don't produce end state because not shown an intention to produce end state	Without seeing how the dumbbell can be pulled apart, infants don't (a) imitate the action (there is no action so no imitation possible and no end state is produced), and (b) don't independently form the idea "I could pull this apart" (so no end state – pulling dumbbell apart – is produced)
Behne, Carpenter, Call, and Tomasello (2005): 9-month-olds and up	*Finding*: Experimenter *unwilling* or *unable* to give toy to child. *Unwilling*: (a) looked at infant and withdrew toy when infant reached for it, (b) looked between toy and infant, (c) showed toy to infant while looking at toy. *Unable*: distracted, attempting but unsuccessful	*Unwilling*: The experimenter focuses attention on the toy, making it salient, but makes no attempt to give toy to infant ⇒ infants' experience in world enables understanding that will not receive toy when experimenter acts in this way ⇒ infants signal their frustration and desire for help from someone else (by looking away) and signal again to experimenter to give toy (by reaching for it)
	Infant reaches more for toy and looks away more when experimenter unwilling	*Unable*: Experimenter's actions (to retrieve toy or talking to others) provide a constant distraction from toy for infant (so not frustrated) and indicate infant might yet receive toy once finished talking to others or once successful retrieval ensues ⇒ infant doesn't get frustrated and doesn't feel need to signal for toy

[a] Also see text and Ruffman et al. (2012).

of the state they seek to influence (attention). The child simply does these things because they lead to a more pleasing interaction. Likewise, a child's decision as to whether to follow the gaze of a blindfolded other might rely, not on mentalistic insight, but on the outcome when she herself previously wore a blindfold, recognizing that the opaque blindfold does not afford successful action, but the transparent one does.

Moreover, self-experience with blindfolds is not essential for infants to learn about blindfold properties. Eighteen-month-olds witnessed a blindfolded adult reach for objects on a table, or fumble and not grasp objects (Meltzoff, 2013). Infants were more likely to follow gaze when the blindfolded adult had previously been able to grasp objects, indicating that infants can learn about the functional outcomes of blindfolds by observing others. This finding raises the question of how infants conceive of blindfolds and their effects. The infant had no direct experience of the adult's seeing, raising the possibility that s/he followed gaze based solely on the blindfolded adult's previous behavior (capable of reaching for objects versus fumbling and incapable) rather than the visual experience (*sees* objects). In response, a mentalist might argue that children must at least have encoded the agent's goal (to reach for an object), yet an alternative is simply that the infant recognizes instances of functional and dysfunctional behavior in the same way that a female of a species recognizes a more or less impressive courtship display. For instance, the male ostrich throws his wings up, alternately right then left, then drops to the ground while whirling dust with his wings and twisting his neck in a corkscrew fashion (Bolwig, 1973). Just as a female ostrich would not accept the advances of a dysfunctionally behaving male, nor would a child follow the gaze of a dysfunctionally behaving adult.

The aim of other studies has been to examine infant understanding of how perception affects an agent's goal. For instance, Luo and Johnson (2009) found that 6-month-olds' ideas about agent behavior were influenced by whether the agent could see particular objects. If an agent repeatedly reached for object A (when she could see both A and B), then infants expected her to subsequently reach for A and looked for longer if she reached to B. However, if the agent reached for A initially but couldn't see B, then infants did not assume the agent would reach to A rather than B. Luo and Johnson argue that such findings indicate that 6-month-olds understand the agent's goal (to reach for A), and how goals relate to "psychological constructs" stemming from perception (either what is visible with the eyes or perception more generally).

I agree that Luo and Johnson's (2009) study indicates that infants take into account the agent's perception, but it is possible simply that infants recognize how perceptual access affects an agent's (reaching) behavior with no notion of a deeper "psychological construct". Consider a study by Brooks and Meltzoff (2005). They found that 9-month-olds follow head turns whether an agent's eyes are open or closed, whereas 10-month-olds follow head turns only when the agent's eyes are open. Thus, although infants might be interested in the eyes from very early on, 6-month-olds in Luo and Johnson are unlikely to recognize that it is the *eyes*' perceptual access that is crucial for behavior. Moreover, even 10-month-olds (who do recognize the eyes' importance to behavior) need not conceive of the *psychological significance* of eye gaze. They could simply learn to follow head motion and then notice something interesting in the visual field (Butterworth & Jarrett, 1991), or learn from parents that head turns signify something interesting (Moore & Corkum, 1994), leading Meltzoff and Brooks (2007) to conclude that, "there is no silver bullet for ending the debate" as to whether infants understand psychological states or behaviors (p. 232).

What of other tasks examining goal understanding? Thoermer, Woodward, Sodian, Perst, and Kristen (2013) examined 7-month-olds' understanding of grasping with two tasks. In the familiarization phase of the first (expectation) task, infants watched an agent repeatedly reach for one object but not another. In the test phase, infants looked for longer if the agent reached toward the previously ignored object. In the second (imitation) task, the agent either grasped an object (meant to be intentional) or touched it with the back of her hand (meant to be non-intentional). There was a significant correlation between infants' performance on the two tasks such that infants who expected the agent to reach for the object she had previously reached for, also tended to imitate the "intentional" grasp but not the "non-intentional" grasp.

Thoermer et al. (2013) argue that their correlation indicates that infants conceived of both tasks as goal-directed. Yet, again, there is a minimalist explanation rooted in agent behavior. In the expectation task, infants learn the agent reaches for one object, expect her to do so again, and look for longer when she behaves differently. In the imitation task, the infant is confronted with two actions. Infants' familiarity with reaching will likely allow them to anticipate grasping before it happens (because grasping is a reliable follow-on from reaching), and will trigger the infant's independently derived thought to pick up the object (similar to the explanation of Meltzoff, 1995 in Table 3). Their thought to grasp and pick up the object arises, not because they read the agent's intention, but because their observations of the agent's reaching, and their own experience of reaching and grasping, triggered an anticipation of the act of grasping, picking up and exploring in some way (because ordinarily one does not just reach and grasp an object, *one then does something with it*). In contrast, infants' lack of familiarity with a back-of-hand gesture does not allow them to predict any ensuing action when they see the agent touch it with the back of her hand, so they do not get the idea that the object can be picked up and explored, and there is no reason to touch an object with the back of their hand.

The present account holds that young infants attend to agent–*object* relations rather than agent–*space* relations (i.e. reaches to a particular object rather than side) because: (1) they represent objects as distinct entities (Spelke, 1990), (2) the agent repeatedly reaches to and touches the object, making the object salient rather than the side, and (3) infants quickly learn that objects are interesting because of their varied colors, textures, tastes, and functions. For these reasons, it seems entirely reasonable to posit that agent–object relations would be preferentially encoded in such situations.

Other studies have used computerized objects that lack animate features like eyes or hands. Gergely, Nádasdy, Csibra, & Bíró, 1995 habituated children to a computerized ball that moved on a straight path until it reached a barrier, then jumped over the barrier and continued onward. In the experimental phase, there was no barrier and the ball either repeated the previous jumping action or it continued on a straight path throughout, with infants looking longer at the former action. Likewise, Csibra, Bíró, Koós, and Gergely (2003) habituated children to a display in which a small ball continued on a straight path through a gap in two barriers, whereas a ball too large for the gap swerved around the barriers. In the experimental phase, the paths of the two balls were either the same as above (even though the large ball would now fit through the gap) or both balls travelled through the gap. Twelve-month-olds looked longer at the former event. Gergely and colleagues argue that infants employ a teleological stance (reasoning about outcomes rather than mental states) on the basis that behavior is rational (with no need to divert from a direct path unless there is a barrier).

Although lacking eyes, hands and other human features, the objects in these experiments display properties of animate motion; they are self-propelled and travel along non-linear paths (e.g. swerving or jumping). These characteristics likely allow infants to succeed using their prior experience of animate motion, without direct experience of each and every type of potential agent. The same is true of adults. Consider that you see a weird alien-like organism coming toward you one night. Although you have never seen such a creature previously, if it displays even a few of the characteristics of animate motion you could predict it's likely path and move out of the way. Infants' primary exposure to animate motion is through human motion. Humans do not jump unless there is a barrier and they do not deviate around a barrier if a direct path takes them through a gap. Because the objects in Gergely and colleagues' tasks display features of animate motion, infants will expect the ball to travel on a linear path close to the ground rather than jumping if there is no barrier, and the big ball to travel on a direct path through the gap if the gap is big enough. The motion cues in these stimuli provide infants with ample information for anticipating future actions without any reference to mental states.

In sum, studies examining perception, goals and intentions have been repeatedly argued to demonstrate that infants understand mental states, yet also have a clear minimalistic interpretation. Nor is it at all evident that there are two subsystems of development. It is equally possible to construe infant performance on all ToM tasks as providing converging evidence for a single skill (pattern recognition) that allows them to predict behavior and pass a greater number of tasks as their experience of the world accumulates. In the next section, I examine the idea that infant understanding of behavior is implicit.

Implicit versus explicit knowledge

In the section on parsimony, I considered infants' use of rules in false belief tasks, following a tradition in which infants are said to possess behavior rules (e.g. Perner & Ruffman, 2005). Yet, although this is a convenient way for an observer to describe an infant's understanding, it might bear little relation to the infant's actual insight. From the infant's perspective, she might simply be processing ongoing information. Neurons remember information in both an active manner through sustained firing in the prefrontal cortex, and in a latent manner through altered firing thresholds in non-frontal regions (Morton & Munakata, 2002). An infant looks longer at an unexpected outcome because the agent's actions violate the output of her processing (based on previous and within-experiment experience), leading to additional processing. Similarly, the infant looks in anticipation to a particular location when anticipating the agent's searching because processing of previous instances of agent behavior produces that output. Yet, the infant might not have any awareness whatsoever of the "rule" that she seems to be following and in this sense the knowledge is implicit (Dienes & Perner, 1994).

The idea that children don't (initially) learn rules is consistent with what is known about children's learning of complex information. For instance, Pacton, Perruchet, Fayol, and Cleeremans (2001) examined children's acquisition of orthography in a school setting over a five-year period. If children learn rules, then their learning of a rule with one set of stimuli should transfer such that performance on a second set of stimuli is equivalent. In contrast, if children learn in a more piecemeal fashion about regularities in a particular stimulus set, their performance with the new stimulus set should lag behind. Pacton et al. found that performance on novel material consistently tended to lag behind that on familiar material indicating that initial learning falls short of the necessary criteria for rule use.

Connectionist models are informative when examining such issues because (a) they can learn, (b) their learning is not the learning of "rules", but of associations based on probabilistic input, and (c) they can be used to model transitions from implicit to explicit knowledge. Recently, Berthiaume, Shultz, and Onishi (2013) used a connectionist model to simulate false belief understanding. The network encoded the original and subsequent location of an object, and whether an agent had seen the object's movement. It included more true- than false-belief training trials (agent sees transfer) on the assumption that these are more frequent in life, and 15% of trials were error trials in which the agent's search contradicted their perceptual access (assuming some forgetting or distraction in real life). The model initially predicted the agent would search at the correct location (due to more true belief trials), then later that the agent would search at the last location where the object was seen. Berthiaume et al. conclude that the network "categorized training patterns on the basis of belief" (p. 451).

Berthiaume et al.'s (2013) model shows that it is possible for a system to learn to connect perception to behavior even when there are training trials that add "noise" because search does not correspond to perception. On the other hand, their interpretation of what the model is actually doing seems unnecessarily rich. An alternative interpretation of the model's performance is that it has simply learned to connect perception to *behavior*. This is plausible because what the model encoded was agent perception and object location; there is nothing in the model's encoding or success that necessitates an understanding of *beliefs*.

Nor, I argue, is there anything in Berthiaume et al.'s (2013) model that would permit explicit knowledge. To this end, it is helpful to examine studies of implicit learning because implicit learning is thought to entail learning of patterns and to be an instance of statistical learning (Perruchet & Pacton, 2006). Implicit learning tasks present participants with stimuli that follow complex patterns, for instance, predicting the next location of a stimulus or judging whether novel combinations of letters are grammatical in an artificial grammar, having been exposed to a variety of strings previously deemed grammatical. Slowly, a participant's performance rises to an above-chance level, yet initially, participants insist that they have no confidence in their choices even when they are correct. With enough experience, some participants then eventually develop explicit knowledge such that their confidence in correct responses is greater than their confidence in incorrect responses.

Connectionist simulations of implicit learning demonstrate that the pattern of learning can be modeled with two networks (see Fig. 1). The first network might be similar to that described by Berthiaume et al. (2013) and accounts for implicit knowledge. A second network then takes as input, the output from the first network, and accounts for explicit knowledge (Clark & Karmiloff-Smith, 1993; Lau & Rosenthal, 2011). However, this second network cannot begin functioning correctly until the first network is producing reliably correct output (i.e. correctly predicting behavior on the basis of previous behavior and perception) and this takes time, hence the lag between implicit and explicit knowledge.

These ideas are helpful in understanding the dissociation between children's eye gaze and verbal responses on false belief tasks. Ruffman, Garnham, Import, et al. (2001) had children bet small plastic chips on where they expected the agent to return in a belief task. Although young 3-year-olds looked to the correct location (indexing implicit knowledge), they showed no awareness the agent would go there because they bet all chips on the other (incorrect) location where they said he would go (indexing explicit knowledge). Moreover, a control condition showed that betting was a sensitive measure of confidence. In fact, there seems to be a clear progression to false belief insight from having (a) implicit knowledge but not explicit knowledge, accompanied by high confidence in the incorrect explicit answer, to (b) having implicit and explicit knowledge but low confidence in the explicit knowledge, to (c) having explicit knowledge with greater confidence. Although research now suggests that an implicit understanding of behavior might develop earlier than 3 years of age, this sequence of development still needs an explanation, and once again, the field of implicit learning provides telling insights.

Pasquali, Timmermans, and Cleeremans (2010) examined a confidence measure similar to that used in Ruffman, Garnham, Import, et al. (2001), and found that a model utilizing two networks successfully accounted for the pattern of associations and dissociations between implicit knowledge (performance) and explicit knowledge (betting) on the Iowa Gambling task, an artificial grammar learning task, and in cases of blindsight. The second network succeeded by processing the first network's output, but lagged behind the first network such that the first network produced above-chance performance before the second network. Timmermans, Schilbach, Pasquali, & Cleeremans, 2012 argue that metacognition of the kind demonstrated by Pasquali et al., is but one example of the brain's widespread and automatic tendency to monitor its success (see also Friston, 2008). Two-network models, as applied to false belief, would also allow insight into both own mental states (e.g. own prior false belief) and others' mental states (e.g. others' beliefs), insights that arise at the same time (e.g. Gopnik & Astington, 1988; Moore, Pure, & Furrow, 1990; Wellman et al., 2001).

Although this two-network model provides a compelling framework for understanding development, I note two caveats when comparing connectionist simulations such as Pasquali et al. (2010) to ToM development in children. First, the precise architecture used to demonstrate explicit knowledge might differ from that shown in Fig. 1. For instance, Pasquali et al. used different architectures, one of which included a three-layer network similar to Fig. 1, but the second had just two kinds of units. Second, in children, the ability to explicitly reflect on another's mental states might also hinge on concurrently developing skills such as language and insight into the self-other distinction (see below), abilities long since mastered by adults.

The idea that higher-order thoughts (Rosenthal, 1993) manifest in a second network are needed for explicit knowledge, gains support from neuroscience studies of various kinds of implicit learning. Whereas, implicit learning is often associated with activity in the striatum, explicit learning is associated with the frontal cortex (Aizenstein et al., 2004; Destrebecqz et al., 2005; Reiss et al., 2005; Yang & Li, 2012). Importantly, explicit knowledge is accompanied, not just by increased frontal activation, but by an increase in *connectivity* between the frontal cortex and other brain areas such as the striatum, hippocampus or occipital lobes (Carter, O'Doherty, Seymour, Koch, & Dolan, 2006; Destrebecqz et al., 2005; Fletcher et al., 2005; McIntosh, Rajah, & Lobaugh, 1999; Rose, Haider, & Büchel, 2010; Wessel, Haider, & Rose, 2012; Yang & Li, 2012). In other words, neuroscience is consistent with Pasquali et al.'s (2010) connectionist model of explicit knowledge requiring communication between two networks. In contrast, Berthiaume et al.'s (2013) single-network model could be conceptualized as revealing implicit learning of the link between perception and behavior, and would not be dissimilar to other kinds of implicit learning. For instance, rats' learning of a new motor skill (reaching with a leg) is accompanied by strengthening of connections in the motor cortex (Rioult-Pedotti, Friedman, Hess, & Donoghue, 1998). As in Berthiaume et al., rats' new knowledge is accompanied by strengthening of connections, but it seems far safer to say that the knowledge is implicit rather than explicit.

Contributors to an explicit ToM

Eventually, children acquire an explicit theory of mind that allows them to provide correct answers when directly questioned in ToM tasks. Whereas mentalist accounts typically focus solely on infant success, an account of ToM should also explain later development. Many studies demonstrate that parent talk assists children's ToM and that children with better language ability do better on false belief tasks.

Infant researchers do not typically address such findings, but I argue that parents and language help the transition from implicit knowledge about behavior to explicit knowledge about mental states.

Social input

It is possible that children would eventually infer mental states on their own, perhaps as they notice links between others' perception, behavior, and outcome-based emotional displays (e.g. happiness, frustration). However, research (see Fig. 1) shows that children's acquisition of a ToM is boosted by the presence of other people (Carpendale & Lewis, 2004). Social input – sibling and parental talk about the mental states underlying behavior – likely facilitates both implicit learning about behavior (by focusing children on behavior, helping them to notice patterns), and explicit learning about mental states (by introducing mental state terms that underlie behavior). To this end, children with more siblings pass ToM tasks earlier (e.g. McAlister & Peterson, 2007; Perner, Ruffman, & Leekam, 1994; Ruffman, Perner, Naito, Parkin, & Clements, 1998). Exactly how siblings help children is not clear, but a plausible explanation is that siblings express mental states of their own as well as comment on and explain the reasons for others' actions (Dunn, 1988).

In addition, there are clear links between maternal talk about mental states and a subsequent ToM in normal development (Dunn, Brown, Slomkowski, Tesla, & Youngblade, 1991; Ensor & Hughes, 2008; Meins et al., 2003; Ruffman, Slade, & Crowe, 2002), in deaf children (Moeller & Schick, 2006), and in children with autism (Slaughter, Peterson, & Mackintosh, 2007). In particular, mother talk about the *child's desires* is most helpful for a 15-month-olds' subsequent ToM at 24 months of age, correlating with both mental state language and task performance (Taumoepeau & Ruffman, 2006), whereas her talk about her own or others' desires, and her talk about thoughts and knowledge, are less consistent correlates.

There are likely several reasons for why it helps to talk about the child's desires. First, consistent with simulation theory (e.g. Harris, 1992), it would help children attend to internal experiences. Second, these internal experiences are often highly salient in that they can be felt intensely (e.g. what it feels like to *want X*), and are a frequent source of conflict (as children try to satisfy their desires). Furthermore, this talk encourages the development of explicit knowledge. In the language of connectionism, this would help children to reflect on the output of their own "first-order network", in this case, a brain state and corresponding physiological experience associated with desire (what it feels like to *want X*), as well as linked behavior (e.g. fussing, acting to satisfy the desire). Third, although talk about others' desires can be linked to their external expressions, it cannot be linked to experiences the child herself can feel. Fourth, the child's cognitions (e.g. what it is like to *think X*) are typically not as salient as desires. For all of these reasons, talk about the child's desires seems ideally suited to teach children, over time, to reflect on and understand their experiences as mental states.

Not only is it the case that distinct types of mother talk are differentially effective at different points of the child's development, but mothers assist learning by changing their talk over time. Thus, mothers talk more about the child's desires initially but later increase their talk about others' thoughts and knowledge (Bartsch & Wellman, 1995; Ruffman et al., 2002; Taumoepeau & Ruffman, 2008). This shift in mother talk, might not be consciously mediated, but is perfectly adapted to scaffolding a child's development (see also Csibra & Gergely, 2006).

It will also help if mothers use specific words to describe *different* behaviors. For instance, Ruffman (2013) asked mothers to describe three categories of pictures to children: people reaching for items, people emoting negatively, and people emoting positively. Some mothers used specific terms (e.g. "want") to describe only one category of pictures, but other mothers used specific terms to describe different behaviors (e.g. "He wants it", to describe reaching for an object and a positive expression when receiving an object). Children's mental state language was also examined at 9, 15, 21 and 27 months of age, and then again 6 months later. When mothers used specific terms in a variety of situations, the oldest age group had a vastly improved mental state lexicon 6 months later. The key variable was not the number of times a mother used a word, but whether she used a specific word to describe multiple behaviors. Using the same word (e.g. "wants") to describe such different behaviors will help children to understand the underlying mental state of desire because this is the only thing common to the very different behaviors on display.

In contrast, the three youngest age groups did not benefit from variety in input and there are likely good reasons why. From a statistical perspective, variety can assist a connectionist network in detecting statistical structure, but sometimes the network can be overwhelmed due to processing limitations. Younger children's ability to track the statistical information provided by mothers – "want" referring to not just one, but two or three different behaviors – could be overwhelmed by working memory limitations, resulting in an inability to connect "want" to different behaviors. Alternatively, younger children might be unable to take advantage of input variety because of conceptual limitations. Using one word to describe different behaviors would be an advantage when children are in a position to learn about underlying mental states, but otherwise could confuse.

Self-other distinction

Besides contributions from siblings and parents, it is likely that developments in other areas assist ToM understanding. For instance, children will be better able to take advantage of talk about others' desires when they have a good distinction between "self" and "other" (see Fig. 1). Knowledge of this distinction is measured by examining diverse insights such as children's ability to identify themselves in a mirror, their use of pronouns to refer to self and other, and by their empathic behavior toward others, insights that develop as early as 18–24 months of age (Bischof-Köhler, 1991; Lewis & Ramsay, 2004), and Taumoepeau and Reese (2014) showed that children with better self-recognition received a bigger boost to their ToM from siblings. Recognizing the difference between self and other would better allow infants to understand when mental state talk refers to others and how others' mental states might differ from the child's own mental states.

Language ability

Language will enable a child to learn about behavior from an utterance about behavior, and mental states from an utterance about mental states. Interestingly, there is a parallel between how language relates to implicit learning on the one hand, and to eye gaze in ToM tasks on the other. Implicit learning is independent of (a) language ability (e.g. Cherry & Stadler, 1995; Vinter & Perruchet, 2000), and (b) eye gaze in ToM tasks (Low, 2010; Ruffman, 2000; Ruffman, Garnham, & Rideout, 2001).

In contrast, an explicit ToM reliably correlates with children's language ability (Milligan, Astington, & Dack, 2007), and likely does so for a number of reasons. First, a well-established finding is that a nascent understanding of language bootstraps further insight into language (e.g. Ferguson, Graf, & Waxman, 2014). Consider the statement, "Fle gloms tiy rop". A failure to understand any of the words of this utterance makes it impossible to infer the meaning of one word ("glorm"). In contrast, consider, "He glorms the present" (where "glorms" might refer to a mental state such as *wanting*). Language contains *frequent frames* in which the grammatical categories of nouns and verbs assume statistically predictable positions in an utterance (Mintz, 2003). If one understands "He" and "the present", it is possible to infer that glorms is likely to be a verb and will relate to the relation between "He" and "the present". If the utterance describes a picture or something currently visible (e.g. someone reaching for a present), it might be possible to infer what "glorm" likely means. Thus, having a good vocabulary and knowledge of frequent frames will facilitate an understanding of mental state words and ultimately mental states.

Second language helps to make explicit, different perspectives on the same event (Clark, 2004). Children who have a better grasp of language can understand someone's explicit statement of desire (e.g. "I like eggs"), and will be better placed to understand that statement as expressing a mental state different to the child's own (e.g. "I don't like eggs"). Third, understanding the nuances between different expressions (e.g. "thinking that" versus "thinking of") will assist distinctions between subtly different mental states (belief versus imagination).

Variations in development

Any framework for ToM development should explain well-established findings. One such finding is that some children pass ToM tasks before others. The present framework explains these findings as a function of the input children receive. For instance, ToM develops slowly in socially deprived, institutionalized children (Yağmurlu, Berument, & Celimi, 2005) and in deaf children whose parents don't know sign language (Peterson & Siegal, 1995). Indeed, it is not just in children, but in infancy that such differences are displayed. Thus, hearing infants are significantly better than deaf infants (*M* age = 23 months) on a false belief task employing looking time as the dependent measure (Meristo et al., 2012). Moreover, maternal mental state language to deaf children is reduced relative to hearing children (Morgan et al., 2014). Such findings have no apparent explanation if ToM is innate but are easily explained if children benefit from mother talk about mental states.

These findings do, however, raise a question about how, exactly, the hearing infants in Meristo et al. (2012), or even more strikingly, the 7-month-olds in Kovács et al. (2010), might benefit from maternal talk. Whereas, older infants will benefit because they understand the meaning of the words, the benefit for non-linguistic hearing infants might be that talk draws attention to events relevant for learning about behavior. If a mother comments on how much she likes a bowl of ice cream, an infant who has no understanding of language but can hear, will be drawn by the mother's vocalizations to observe her actions and facial expressions as she eats. This will help the infant to predict future behavior (e.g. when she looks at object A and she smiles, the pitch of her voice will rise, she will reach for A, eat A, etc.).

A second well-established finding is that children come to understand desires before beliefs. It has usually been argued that desire is understood before belief because only belief requires children to understand mental states as *representations* (Perner, 1991; Wellman, 1990). However, another way of understanding this developmental pattern is to consider how the input – the statistical information about behavior and the linguistic input from siblings and mothers – might differ. First, consider the statistical information regarding agents' behaviors. For belief, children must recognize that agents see objects in particular places and then go to those places. Perception is intrinsically linked to belief; we believe an object is at X because that is where we have seen it. For desire, children must recognize which object an agent reaches for or looks at when emoting, but distinguishing between seeing and not seeing is not intrinsic to understanding desire because desires are typically expressed in the presence of objects. Opportunities to learn that people look for objects where they last saw them (when the object has been moved) are likely infrequent (Berthiaume et al., 2013) so that learning about beliefs will be slower than desires.

Also relevant is the input from siblings and parents. Mothers talk more about desires initially and later increase their talk about thinking (Bartsch & Wellman, 1995; Taumoepeau & Ruffman, 2008), and this is paralleled by children's own use of these terms: 68% of 26-month-olds use "wanna", whereas only 22% use "think" (Dale & Fenson, 1996). Likewise, frequent disputes with siblings (e.g. tussles over toys) often result in siblings expressing their desires to the child (Dunn, 1988). It is plausible that the more frequent familial talk about desires is a second factor that explains why children understand desires before beliefs. Thus, both factors – the statistical information about behaviors and the input from siblings and mothers – would predispose infants to learning about desires before beliefs.

Although it is not possible to state with any certainty the exact age at which children acquire an understanding of desires or beliefs *as mental states*, an understanding of desire might be achieved sometime around 2 years of age. Several factors combine to make this likely: (1) the child distinguishes between self and other, (2) children's receptive language is relatively good, helping them to benefit from maternal talk about desires, (3) it is mother talk about the *child's* desires that is most closely associated with development in ToM between 15 and 24 months, and such talk will help children to reflect on their own inner experiences and understand them as mental states, and (4) mothers' use of specific terms to describe different behaviors is helpful only for 27-month-olds' subsequent ToM (but not younger children's), with such talk helping children to understand that mental state terms refer to mental states rather than specific behaviors. Nevertheless, these comments are *suggestive*. There is no *proof* that such children understand mental states. These factors merely make it more likely that they do.

Those who argue that ToM is innate or very early developing do not typically consider this wider literature linking ToM to social input and children's language ability, yet it is just as relevant and in need of explanation. If ToM is innate, why is it that mother talk about mental states is helpful for subsequent ToM, and why talk about the child's desires in particular? If infants already understand mental states, what accounts for the pattern of development and confidence ratings obtained by Ruffman, Garnham, Import, et al. (2001)? Such findings are easily explained by positing that children build on an implicit understanding of behavior to develop an explicit understanding of mental states. Infancy researchers seem to have assumed that their findings simply supplant this body of literature, yet it is just as relevant and in need of explanation for a comprehensive account of ToM development.

Conclusion and future directions

In attempting to situate the arguments herein about children's ToM, it is helpful to turn to a classic debate regarding "rich" interpretation. Whereas Haith (1998) and others argued against rich interpretation of infant cognition, Spelke (1998) proposed that skeptics should adhere to four principles.

1. *Intuition*. Haith (1998) claimed that rich interpretation in infancy was non-intuitive but Spelke (1998) argued that empirical findings should take precedence. In fact, I agree completely with Spelke's claim. Interestingly, for most, intuition is now on the side of rich interpretation. Infant mentalism is said to be "plausible" and "parsimonious", whereas minimalism is said to be "implausible" and "post hoc". Yet currently, mentalists have only their intuitions to draw on because the empirical findings indicate a minimalist account is perfectly viable.
2. *Fair consideration*. Spelke (1998) argued that no hypothesis should be considered "guilty" or "proven" without fair consideration. The current consensus is that Perner and Ruffman's (2005) account cannot explain recent false belief findings so that infants must therefore understand mental states. Yet Perner and Ruffman's account was constructed to explain a single study. Fair consideration requires examination of a minimalist account designed to be more comprehensive, like the present account. Further, mentalist theory should not be so easily considered "proven", because as demonstrated here, minimalism also explains the data.
3. *Plausibility*. Spelke (1998) claimed that a theory arguing against rich interpretation must provide clear and plausible processes that explain the phenomenon to avoid an "impossible standard" whereby every alternative claim (however implausible) must be eliminated for an account to be valid. The present framework is based directly on research evidence so there should be no disputing its plausibility as long as an adult human can set aside her/his own bias for rich interpretation.
4. *Comprehensiveness*. This review has been careful and thorough, addressing paradigmatic ToM studies. Further, the infant research is integrated with findings for children so that the present account is arguably more comprehensive than mentalist accounts based mainly on infant findings.

In sum, each of the points raised by Spelke (1998) has been carefully addressed, yet I have argued against rich interpretation of data. Many avenues remain for future research, such as examining the role of statistical learning more directly, and conducting longitudinal research that is micro-genetic to help elucidate relations between contributing factors and ToM rather than the current snapshots of performance at different ages. Also of interest is why primates (Call & Tomasello, 1999; Krachun, Carpenter, Call, & Tomasello, 2009; Marticorena, Ruiz, Mukerji, Goddu, & Santos, 2011) and children with autism (e.g. Baron-Cohen, Leslie, & Frith, 1985) fail false belief tasks. Reduced or absent maternal talk about mental states is one potential cause and reduced statistical learning is another. Children with autism have noted difficulties with both ToM and language, which could implicate both maternal input and statistical learning. Indeed, there is evidence that both primates (Conway & Christiansen, 2001) and individuals with autism (Frith, 1970a, 1970b; Gordon & Stark, 2007; Mostofsky, Goldberg, Landa, & Denckla, 2000; Müller, Cauich, Rubio, Mizuno, & Courchesne, 2004; Müller, Kleinhans, Kemmotsu, Pierce, & Courchesne, 2003) have less sophisticated statistical learning skills. It could also be that children with autism have reduced opportunities for learning about perception-behavior links because of reduced attention to agents and agent–object interactions.

In sum, although many different researchers have claimed that infants understand the mental states of perception, goals, intentions and beliefs, I have provided a framework outlining how children could, on the basis of their attention to people and motion and their good pattern recognition abilities, develop an implicit understanding of behavior that allows success on ToM tasks. They then develop an explicit understanding of mental states through maternal dialogue about mental states and their own developing language and self-recognition skills.

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