False belief understanding in infants and preschoolers

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INTRODUCTION TO CONTROVERSIES IN FALSE BELIEF RESEARCH

A mature, everyday understanding of human behavior rests on having a representational theory of mind--an understanding that observable actions are motivated by internal mental states such as intentions, desires, and beliefs (Wellman, 1990). The term "representational" is used to capture the fact that mental states, in particular the epistemic mental states of knowledge and belief, are representations of some putatively true state of affairs and their formation is due to, and limited by, a person's experience of the world. The term "theory of mind" captures the fact that we use these abstract mental state conceptualizations to both explain and predict others' behavior, just as any theory allows us to explain and predict relevant phenomena. A number of researchers and theorists have suggested that having a representational theory of mind provides the foundation for several important aspects of social-cognitive functioning, such as teaching and learning, lying and pretending, making and keeping friends, and social learning more generally (Tomasello, 2009).

Because of its fundamental importance, cognitive developmentalists have been especially interested in charting the development of representational theory of mind abilities in young children. Based on suggestions from Dennett (1978), researchers developed a task thought to diagnose a representational theory of mind in children called the "false belief" task. In a typical false belief task (e.g., Baron-Cohen, Leslie, & Frith, 1985; Wimmer & Perner, 1983), a story character puts a desirable object in one hiding place, and then leaves the scene. In her absence, a second character moves the object from the original hiding place to another hiding place. Thus, the child observer and second character know where the object really is, but the first character does not. Children are then asked to predict where the first character will look for the object. This is argued to be a clear test of a representational theory of mind because children must

reason about the first character's belief as separate and distinct in content from the reality that the mental state is supposed to faithfully represent (Perner, 1991). The typical finding from these studies is that children around their third birthday fail to show an understanding of false belief, predicting that the first character will instead look where the object truly is. Then, sometime between 3 and 5 years of age, children gradually come to show false belief understanding by correctly predicting that the first character will look where she left the object originally.

The false belief literature is large, in part because there has always been a question of whether the false belief task actually underestimates infants' and young preschoolers' abilities to reason about others' representational mental states (Moses & Chandler, 1992). Early on, researchers noted that there were many things within the everyday behavioral repertoires of even 2-year-olds that entailed a representational understanding of others' minds. Among these everyday behaviors were lying (Chandler, Fritz, & Hala, 1989), teasing (Reddy, 1991), monitoring others' knowledge and ignorance (O'Neill, 1996), and talking about mental states in ways that seemed to demonstrate an understanding of false beliefs (Bartsch & Wellman, 1994; Shatz, Wellman, & Silber, 1983). These researchers (called "boosters" by Chandler et al., 1989) argued that children fail false belief tasks, perhaps not because they lack a conceptual understanding of representational mental states, but rather because false belief tasks are too complex, unnatural, and rely to a great extent on cognitive capacities other than a conceptual understanding of others' minds (such as language, working memory, and executive control). The working hypothesis was that a representational theory of mind might be very early emerging or innate, although its expression across a variety of situations may be quelled by children's slow maturing abilities in other domains.

On the other side of the debate, another group of researchers argued that these rich

interpretations of infants' and young preschoolers' everyday behavior were unwarranted and that such behaviors could be accounted for by mechanisms simpler than a representational understanding of mental states (see, e.g., Perner, 1991). For these researchers, it was not necessarily that infants and younger children had *no* understanding of mind – rather, that their understanding early in development was immature and did not encompass a representational understanding of mental states (Gopnik & Wellman, 1994; Wellman, 1990). In line with the results from the false belief studies and studies that appeared to also require an understanding of misrepresentation, such as the appearance-reality task (Flavell, Green, & Flavell, 1986), researchers argued that a representational theory of mind begins to emerge during the fourth year (see e.g., Wellman, Cross, & Watson, 2001). Importantly, the underlying ability to think about misprepresentation is described as a new conceptual development that emerges at the end of the preschool period, rather than as a change in the ability to express some already present but nascent understanding (Wellman & Gelman, 1998).

Much of the research that came out of this debate involved studies that tweaked the false belief task to weaken the properties that were theorized to muffle young children's performance. Tasks were designed to increase the naturalism, decrease the memory demands, decrease the linguistic demands, clarify the intention behind the test question, and make the responses less at odds with children's natural tendencies (Carlson, Moses, & Hix, 1998; Lewis & Osborne, 1990; Moses & Flavell, 1990; Perner, Leekam, & Wimmer, 1987) After about 15 years of concentrated interest, Wellman et al. (2001) summarized the effects of many of these manipulations in a meta-analysis. Although many types of manipulations affected performance, there was no evidence that any particular manipulation (or even groups of manipulations) improved 3-year-olds' performance to above-chance levels — a clear criterion for demonstrating systematic

understanding. The uneasy consensus that appeared to emerge over this period (largely supported by the meta-analysis) was that false belief tasks constitute valid, robust measures of theory of mind understanding for preschool children. Infants' mentalistic understandings then were typically thought to be limited to other kinds of mental states and "precursors" of false belief, such as desires (Wellman & Woolley, 1990), intentions (Woodward, 1998), attention (Moore, 1999), and emotions (Phillips, Wellman, & Spelke, 2002), and social attributes (Kuhlmeier, Wynn, & Bloom, 2003).

Over the last 5 years, this uneasy consensus has given way in the wake of findings that have assessed infant's understanding of false belief using looking time methodologies. These methodologies have revealed that 14- to 24-month-olds show the ability to predict the false-belief-based behavior of those around them. In a study by Onishi and Baillargeon (2005), violation-of-expectation methodology was used to test false belief knowledge in 15-month-olds. During familiarization, infants were shown a scene where an agent hid an object in one of two locations. The object then moved to an alternative location, either while the agent was observing (true-belief condition), or while she was unable to see the object's movements (false-belief condition). A test trial followed during which infants' looking times were measured while observing the agent reaching to either the outdated or current object location[1]. In true belief conditions, infants looked longer when the agent searched in the outdated location. Infants in false belief conditions showed the reverse looking-time pattern, looking longer when the agent searched for the object in its current location. Since then, these findings have been replicated and extended to even younger ages, with researchers finding evidence for knowledge of false-belief-

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[1] Kagan (2008) has recently summarized a number of critiques of the infant looking-time methods that are used in these and other studies. For our part, we will take the infant data at face value and go on to offer other empirical and theoretical reasons to doubt their specific conclusions.

based behavior in infants as young as 13 months of age (Surian, Caldi, & Sperber, 2008).

These findings have catapulted the "booster" hypothesis that a representational theory of mind is either early emerging or innate into the leading position. Indeed, this was expressed most clearly in a recent paper from Southgate, Senju and Csibra (2007) who report that 2-year-olds' eye movements while watching a false belief scenario show evidence that they correctly predict a protagonists' false-belief-based actions. In interpreting these findings, they write:

> "Our measure showing that 2-year-olds predicted the behavior of an actor on the basis of a false belief provides compelling evidence for an early-developing reliance on epistemic state attribution in predicting actions, and is incompatible with the position that children are able to attribute false beliefs only after undergoing a conceptual revolution between 3 and 4 years of age (Gopnik & Wellman, 1992). Our data are more consistent with the position that children's difficulties on false-belief tasks stem from performance limitations, rather than competence limitations (Surian & Leslie, 1999)." (Southgate et al., 2007, p. 591).

The goal of the rest of this chapter is twofold. First, we briefly outline what we think is the most plausible "performance limitation" account of preschoolers' theory of mind failures – the executive function account – and show that this account is not plausible given the extant data that has tested the most direct predictions of the account. Second, we sketch a position in which we argue that the substrate for young infants' success on looking-time false belief tasks consists, not of the same conceptual framework that older children and adults use, but rather of an innate and evolutionarily old system that enables infants to perform *sequential episodic encoding* of events. The power of just such a system, we argue, can be seen in the surprisingly sophisticated behavior of a variety of non-human species (including birds) that putatively (and in some cases demonstrably) do not have a representational understanding of mental states.

AGAINST A PERFORMANCE ACCOUNT OF PRESCHOOLERS'

FALSE BELIEF FAILURES

Executive functioning is the term often used to refer to the suite of cognitive functions that support goal directed behavior and cognitive control across conceptual domains, including response inhibition (or inhibitory control), working memory, error monitoring, rule representation and use, and attentional control (Zelazo, Carlson, & Kesek, 2009). Researchers have long noted that false belief tasks place clear demands on executive functioning in at least three ways. First, responding appropriately in a false belief task requires one to point to where something is *not*. Doing so may require a modicum of executive functioning to overcome a prepotent (or habitual) tendency to point to where something truly is (Carlson et al., 1998). Second, false beliefs, although not uncommon, are likely to be rare occurrences relative to true beliefs. Thus, to think that a given belief might be false, one might need to overcome a habitual tendency to reason that the belief is true (Leslie & Polizzi, 1998; Sabbagh, Moses, & Shiverick, 2006). Finally, the false belief task requires children to keep two conflicting perspectives on the same situation in mind at once and then determine which is more appropriate given the context of the test question (Frye, Zelazo, & Burack, 1998). For these reasons, researchers have suggested that the executive demands inherent to false belief tasks may be the root cause of preschoolers' failures on the tasks -- not their inability to reason about false beliefs.

Current support for an executive account is inconclusive

Currently, evidence in support of the executive account of 3-year-olds' failure comes in two forms. The first is that individual differences in preschoolers' executive functioning, in particular on Stroop-like tasks that pit one habitual or recently learned response against a

competitor, predict performance on false belief tasks (Carlson & Moses, 2001; Hughes, 1998; Perner, Lang, & Kloo, 2002; Sabbagh, Moses, et al., 2006). As a number of researchers and theorists have argued, though, there are many possible interpretations of this relation. Thus, these findings do not provide conclusive evidence for the hypothesis that 3-year-olds' failure is attributable to the surface demands of executive functioning tasks (see e.g., Moses, 2001; Moses, Carlson, & Sabbagh, 2004). Moses (2001) argued that an equally plausible alternative hypothesis regarding the relation between false belief performance and executive functioning is that executive functioning promotes conceptual advances in the ability to reason about false beliefs (Russell, 1996). Indeed, as we will discuss in more detail below, a recent review of the now extensive literature on the relation between false belief and executive functioning shows that this alternative hypothesis more comprehensively accounts for the range of findings (Benson & Sabbagh, 2009).

The second line of evidence in support of the executive account is that titrating the executive demands of a false belief task has highly predictable effects on performance. Leslie and colleagues have clearly demonstrated that raising the executive demands of the false belief task by, for instance, adding additional locations, leads to poorer performance (Friedman & Leslie, 2004). Conversely, reducing the demands of the task by changing the response modality or by making the true state of affairs less salient leads to improvements in 3-year-olds' performance on the task (though, rarely do they show above-chance performance). It is in this light that the false belief findings with infants are so interesting. On all accounts, the requirement to make a response is the task factor that imposes the most serious executive demands. Because infant looking time paradigms do not require an explicit response and thus putatively tap only the computation of the false belief, they may constitute false belief tasks that are essentially free of

executive demands (Scott & Baillargeon, 2009).

Over the next few sections we intend to call this interpretation of the infant data into question. Namely, we will review literature showing that straightforward hypotheses of an executive account of young preschoolers' failures in false belief tasks are either not supported or directly contradicted. In addition, we will note that the false belief task has external validity as a measure of conceptual change in the preschool years, thereby bolstering the case for a qualitative conceptual change in theory of mind reasoning over the preschool years.

Cross-cultural Evidence

The main contention of the executive account of young preschoolers' false belief failures is that standard false belief tasks require some level of executive functioning to negotiate the demands of the task. The mechanism for false belief development, then, is the development of executive functioning. Furthermore, once children's executive functioning skills have matured to some criterion level necessary for negotiating the demands of the task they will reveal their false belief knowledge and understanding. Skillful performance on the response-conflict Stroop-like tasks is generally thought to be an index that children's executive skills have matured to that criterion level, which is why their performance on the false belief task correlates with performance on Stroop-like tasks. However, there is now strong evidence to suggest that attaining a particular level of performance on response-conflict executive functioning tasks does not, in and of itself, lead to correct performance on false belief tasks. This evidence comes from cross-cultural work on the relation between executive function and false belief performance.

In East Asian cultures, parents and teachers place particular emphasis on the socialization of self-control in their preschool-aged children (Chen, et al., 1998; Ho, 1994; Tobin, Wu, & Davidson, 1989). Because of this socialization, and perhaps also cross-cultural differences in the

neurotransmitter systems that affect frontal lobe development and executive functioning performance, such as dopamine (Chang, Kidd, Kivak, Pakstis, & Kidd, 1996), some researchers have hypothesized that children from East Asian cultures may have earlier developing executive functioning skills relative to their more Western counterparts (Chen et al., 1998). A critical question, then, concerns whether Chinese preschoolers do indeed have advanced executive functioning skills, and if so, whether they also have advanced theory of mind development.

Sabbagh and colleagues (Sabbagh, Xu, Carlson, Moses, & Lee, 2006) studied preschool-aged children from Beijing, China. The study used the same procedure and assessments that Carlson and Moses (2001) used in their study of the relation between executive functioning and false belief performance. The comparison of results across the two cultural groups was striking (see Figure 1). On every task of executive functioning that was tested, the Chinese preschoolers outperformed their North American counterparts. In the aggregated data, the Chinese preschoolers' performance on the executive functioning battery was roughly 6 months ahead of the North American preschoolers (i.e., on average, 42-month old Chinese children had scores on a par with 48-month old North American preschoolers). Yet, despite this striking advantage in executive functioning skills, the Chinese preschoolers were no different from the North American preschoolers in their theory of mind development.

If we assume that some criterion level of executive functioning is necessary for performance on the false belief task, we can assume that many of the 48-month-olds from the North American sample had achieved that level of functioning, given their strong false belief performance. However, the 42-month-old Chinese children had, on average, achieved the same level of executive functioning performance as the North American. Thus, many 42-month-old Chinese had reached what should be considered a criterion level of executive maturation that

should, if false belief understanding is indeed early developing, have allowed them to solve the false belief tasks. The fact that 42-month-old Chinese remained unsuccessful at false belief despite having executive performance on par with 48-month-old North American children who did do well at false belief tasks shows that executive maturation alone does not account for preschoolers' false belief development.

This same pattern of findings has now been replicated in studies with Korean children (Oh & Lewis, 2008) and children from Hong Kong (Tardif, Liu, & Wellman, 2009). The findings from all of these studies show that, despite substantially advanced executive functioning skills, 3-year-olds in East Asian cultures show the stereotypical pattern of poor performance on false belief tasks. Indeed, if anything, children from East Asian cultures may lag behind North American preschoolers in theory of mind development (Liu, Wellman, Tardif, & Sabbagh, 2008). These findings provide a clear set of evidence against a simple executive function account of preschoolers' theory of mind development; as a group, East Asian preschoolers have a developmentally advanced trajectory of executive functioning, but no advantage in false belief performance.

<div align="center">Developmental Cognitive Neuroscience Evidence</div>

A second line of evidence that suggests that young preschoolers' theory of mind development represents bona fide conceptual developments comes from research on the neural bases of these skills in young children. In adults, there is now a substantial body of literature reporting on the neural bases of theory of mind. An exhaustive review of this work is beyond the scope of this chapter. By way of summary, recently published reviews have highlighted the contribution that two areas make to reasoning about one's own and others' mental states; namely circumscribed regions of the dorsal-medial prefrontal cortex (MPFC) (Amodio & Frith, 2006)

and the right temporal parietal juncture (rTPJ) (Saxe, 2006). Of these two areas, an emerging body of work from Saxe and colleagues suggests that the rTPJ may be recruited more specifically for reasoning about the representational nature of mental states, whereas the dMPFC may be recruited when reasoning about triadic social cognitive relations more generally (Perner & Ruffman, 2005; Saxe & Powell, 2006). What is important with respect to the current discussion is that the neural bases of theory of mind are clearly dissociable from those that underlie response-conflict executive functioning skills. In a recent review analysis, Ridderinkhof, Ullsperger, Crone, and Nieuwenhuis (2004) showed that performance on executive functioning tasks, particularly the Stroop-like tasks that are most strongly associated with false belief performance, tend to activate a region of the MPFC that is posterior to the region associated with theory of mind reasoning, and proximal to the cingulate cortex. In another review analysis, Bunge and Zelazo (2006) showed that another, often overlooked, aspect of response conflict executive functioning that entails keeping in mind and integrating a hierarchy of interrelated rules is associated with the ventral-lateral prefrontal cortex (VLPFC) in adults, and perhaps in children.

The dissociation between the neural regions associated with theory of mind and those associated with executive function has been shown perhaps most clearly in research by Saxe and colleagues (Saxe, Schulz, & Jiang, 2006). In their study, participants were given a pair of tasks that compared the neural activations elicited during theory of mind reasoning with those associated with the executive functioning skills that are required to negotiate theory of mind tasks. Indeed, the two tasks were identical except for their instructions: in one case they were encouraged to reason in a rule-like way whereas in the other they were encouraged to reason mentalistically. Activations in these tasks were compared with activations in localizer tasks that

measured executive functioning and theory of mind performance independent of the target task. The results showed that when reasoning mentalistically, the usual theory of mind areas were activated (i.e., rTPJ), whereas when reasoning in a rule-like way, the usual executive areas were activated (i.e., anterior cingulate cortex and ventral lateral prefrontal cortex). These findings show that even if theory of mind tasks have executive demands, reasoning about mental states relies upon a distinct neural substrate.

These findings from adults provide a relatively straightforward framework for making predictions about the neuroanatomical developments that are critical for theory of mind reasoning. On the one hand, if executive immaturity were the primary cause of preschoolers' poor performance on theory of mind tasks, we would expect individual differences in theory of mind performance to be paced by the maturation of regions associated with executive functioning (e.g., posterior MPFC, VLPFC). On the other hand, if preschoolers' poor performance were attributable to theory of mind reasoning deficits per se, then we might expect performance to be more related to the maturation of the neural networks that support theory of mind reasoning (e.g., dMPFC, rTPJ).

Sabbagh and colleagues (Sabbagh, Bowman, Evraire, & Ito, 2009) recently investigated these questions using dense array EEG measurements combined with tomographic current source density analyses to assess how individual differences in regional brain maturation predict children's performance on false belief tasks. A number of researchers have shown that the preschool years see major changes in both the power and coherence of brain electrical activity recorded in the alpha band (for children, between 6-9 Hz) (Marshall, Bar-Haim, & Fox, 2002; Thatcher, Walker, & Guidice, 1987). These changes are attributable to the maturational changes that occur as neural populations become more functionally organized. Advances in EEG analysis

techniques have made it possible to use the cross-spectral matrix (essentially a matrix of coherence measures recorded at each electrode) to estimate the extent to which given intracerebral sources contribute to the EEG that is recorded at the scalp. One technique is standardized low-resolution electromagnetic tomography (sLORETA) (Pascual-Marqui, 2002). This allows researchers to assess individual differences in the extent to which any given cortical region is organized. Sabbagh et al. (2009) used sLORETA measures of regional current-source density estimates to determine what aspects of neurocognitive development make unique contributions to theory-of-mind development during the preschool years.

Children's EEG was measured with 128-electrodes distributed over the entire scalp (Electrical Geodesics, Inc, Eugene, OR) while children were resting and looking at a static picture of a rocketship. After EEG recording, children went on to complete batteries of tasks assessing false belief, executive functioning, and language abilities. A series of regression analyses was conducted to determine whether children's theory of mind performance could be predicted from sLORETA estimates of brain activity at each voxel while controlling for children's age, vocabulary development, and executive functioning performance. The results clearly showed that preschoolers' false belief performance was associated with individual differences in the maturation of the theory of mind network, including the dMPFC and the rTPJ. In fact, as is shown in Figure 2, the regions of the dMPFC and rTPJ that were identified as neurodevelopmental predictors of preschoolers' false belief performance were essentially homologous with the regions that are active when adults make theory of mind judgments in experimental tasks.

These findings provide evidence that preschoolers' false belief performance is associated with the functional maturation of the network of brain areas that are typically associated with

theory of mind reasoning in adults, not executive function. Within the context of the present discussion, these findings challenge the emerging view that young preschoolers' failures in batteries of false belief tasks can be attributed to executive immaturity. Instead, these findings support the view that developments in false belief performance reflect a true qualitative conceptual development, whereby young children gradually acquire the ability to reason about representational mental states over the preschool period (Perner, 1991).

Of course, we do not mean to say that false belief tasks have no executive demands, or that executive functioning is unimportant for both the development and use of theory of mind. Reasoning about false beliefs certainly does require executive functioning, and any challenges that an individual has to executive functioning abilities will affect their false belief reasoning abilities. Our point is that the cross-cultural findings show that the developmental extension of this argument (i.e., because false belief tasks require executive function, then executive immaturity is the reason for 3-year-olds' false belief failure) does not provide a compelling account for the extant developmental data. That is, executive immaturity is not the sole cause of false belief failures in preschoolers.

This raises an intriguing question: Why is executive functioning correlated with false belief performance if it is not the case that executive functioning allows children to express an well-formed understanding of beliefs? A full treatment of this question is beyond the scope of this chapter. Briefly, a recent review and summary of the full body of evidence on the question of the relation between executive functioning and false belief suggests that executive functioning may be critical for catalyzing the conceptual developments that themselves enable false belief performance (Benson & Sabbagh, 2009). This account (sometimes dubbed the "emergence" account) predicts that executive functioning will be associated with theory of mind development

via its interaction with experiential factors that are known to also contribute to theory of mind development, such as parent-child talk about mental states (Ruffman, Slade, & Crowe, 2002) and having siblings (Brown, Donelan-McCall, & Dunn, 1996; Perner, Ruffman, & Leekam, 1994). Several studies have linked executive functioning and experience with conceptual change in domains other than theory of mind, including mathematics (e.g., Bull & Scerif, 2001; Blair & Razza, 2007; Espy et al., 2004; McClelland et al., 2007) and language (e.g., Blair & Razza, 2007; De Bani, Palladino, Pazzaglia, & Cornoldi, 1998; McClelland et al., 2007). Thus, in line with these findings, we believe that the "emergence account" provides the most coherent current account of the ontogenetic relations between executive functioning and false belief understanding.

<div align="center">False Belief Performance Has External Validity</div>

Further support for this view that preschoolers undergo a qualitative conceptual change in their theory of mind understanding comes from research showing that false belief tasks have a broad external validity. That is, children's performance on false belief tasks is associated with just the kinds of real-world behaviors that would seem to require of a representational theory of mind. Although the research relevant to this topic is broad, we focus on two examples. In one, Talwar and Lee (2008) argued that the ability to tell a lie to conceal a transgression, particularly one without a serious associated punishment, is predicated on an understanding of false belief. That is, to tell a lie young children must recognize that they can induce another to believe something that is not true (see Chandler et al., 1989, for a similar analysis). Talwar and Lee (2008) induced children to commit a minor transgression against the rules of game, and then interviewed them to assess whether they would admit the transgression or lie. Children's performance on a small battery of false belief tasks was an independent, positive predictor of

lying to conceal the transgression. In a second part of the study, children were interviewed to determine whether they could "keep up" their lie by concealing the knowledge they had gained during their transgression. Here again, children's performance on advanced (i.e., second-order) false belief tasks predicted individual differences in maintaining lies. These findings show that the ability to reason about false beliefs is a critical, independent predictor of just the kind of real-world social behaviors that one would expect of theory-of-mind reasoning.

One might counter that lying may only be associated with false belief reasoning because of a common association with executive functioning abilities. After all, lying almost certainly requires some modicum of executive functioning to overcome one's putatively prepotent tendencies to simply say what is true and known. However, Talwar and Lee (2008) provide evidence against this interpretation. In both of their studies, executive functioning abilities (i.e., performance on a battery of Stroop-like tasks) were assessed and statistically controlled in all of the main analyses. In each case, false belief reasoning was a unique, independent predictor of children's lying performance. These findings further bolster the claim that it is not simply the task demands but the conceptual advances in understanding of false belief that are associated with lying.

In a similar vein, Peskin and Ardino (2003) argued that children's abilities to participate successfully in games like "hide-and-seek" and secret keeping might be related to false belief reasoning because they require children to recognize cases in which others *should* be ignorant of things in the world that they themselves know. Their findings showed that children who were competent at false belief reasoning were more likely to participate in these games correctly. In the case of hide-and-seek, the children who were better at false belief were better able to hide from a seeker without giving away their location, and when playing the seeker role, allow the

hiders to proceed without peeking. Similarly, when keeping a secret, children who were better at false belief were also better at concealing knowledge from a relevant third person. The fact that false belief reasoning is associated with successful participation in these more real-world behaviors provides support for the idea that children's conceptualizations of mind are maturing over the preschool period, with predictable consequences.

A "TWO SYSTEM" APPROACH TO UNDERSTANDING INFANTS' AND PRESCHOOLERS' FALSE BELIEF PERFORMANCE

The bulk of the chapter up until this point has been focused on describing why we do not believe that a "performance account" is an adequate explanation of 3-year-olds' failures at false belief tasks, and why we think that the data with preschoolers is more in line with the notion that children's understanding of belief changes over the preschool period. If we are to say that 3-years-olds do not understand false belief, then we are faced with the question of how to explain the findings showing that infants predict people will act on the basis of false beliefs. One possibility is to take strong interpretations of the infant data at face value and then propose that theory of mind understanding goes through a sort of U-shaped development. That is, at around 2 years of age, infants understand false belief, then that understanding is lost by the age of 3 years, and finally regained over the mid-to-late preschool period. However, there is considerable controversy as to how to best interpret U-shaped patterns of development. More often, researchers argue that U-shaped patterns of development can often be taken as signs of discontinuity in development (Siegler, 2004). That is, the cognitive mechanisms that allow for early competence may be fundamentally distinct from those that support performance later (see Muir & Hains, 2004, for an example from infants' auditory localization).

The same thing may be true of the infant false belief findings. That is, perhaps infants' predictions in the looking response paradigms rely on a cognitive substrate that is fundamentally distinct from the substrate that supports preschoolers' reasoning about false beliefs. There are at least two hypotheses in the extant theoretical literature that have attempted to account for infants' skills with mechanisms other than a bona fide understanding of false beliefs (Apperly & Butterfill, 2009; Perner & Ruffman, 2005). These two accounts bear resemblances to theoretical accounts of how social cognition in non-human species (such as non-human primates and birds) might be distinct from that of humans (at least, preschool-aged humans) (Penn & Povinelli, 2007). In what follows, we will draw on these accounts to delineate how we think infants might make accurate predictions in false belief scenarios, even without a bona fide conceptual understanding of false belief.

<center>Empirical typologies versus explanatory concepts</center>

Gopnik and Wellman (1994) began their explication and defense of a "theory theory" approach to theory of mind development by raising the distinction between empirical typologies and theoretical constructs. Empirical typologies are generalized descriptions of observable phenomena in any given domain. In the domain of human behavior, including false belief understanding, an empirical typology might be something like "people look for things where they last put them" or "people look for things where they last saw them." Gopnik and Wellman (1994) made the point that empirical typologies can be very effective constructs for making predictions about future events. This is largely because the content of an empirical typology is based on, and constrained by, the experience of predictable events. There are, however, limitations on empirical typologies. One is that they are merely descriptive and thus provide no causal explanation for the phenomena under consideration. When the task is to explain others'

behavior in terms of causal mechanisms, then, empirical typologies are not sufficient. A second is that empirical typologies are essentially ad hoc – a list of empirical typologies for predicting some general phenomenon like "where people look for things" can be long, but each item in the list bears no necessary relation to another. The ad hoc nature can occasionally lead to incoherence and, as empirical evidence accrues, contradictory predictions about what others will do (see Perner et al., 1987).

Gopnik and Wellman (1994) argued that children's reasoning can go beyond incoherent empirical typologies and rely instead on theoretical constructs, such as a coherent (even if at times incomplete, incorrect, or otherwise developmentally immature) understanding of belief, how beliefs are formed, and how they shape intentional action. Gopnik and Wellman cite both experimental and naturalistic data to argue that even young children are capable of not just predicting but also *explaining* human actions according to their current theories of mind, but that those theories of mind can be developmentally limited – that is, their explanations and explicit predictions are only as good as their current theories. Perner (2009) has echoed this conclusion by arguing that preschoolers' performance in a wide variety of tasks that would seem to rest on false belief understanding (including appearance-reality tasks, level-two perspective taking tasks, deception tasks, and the very wide-array of false belief tasks) all suggest that preschoolers have a conceptual, theoretical understanding of how beliefs cause intentional behavior.

With Gopnik and Wellman's (1994) distinction in mind, the possibility has been raised that the system that supports *infants'* predictions in false belief scenarios may be more like empirical typologies than abstract, conceptual, causal understandings of belief (e.g., Perner & Ruffman, 2005; see also, Penn & Povinelli, 2007, for the same argument against claims of mentalistic understandings in non-human species). Obviously, this hypothesis is a difficult one to test

empirically. As discussed above, empirical typologies and theories both allow for correct predictions in false belief scenarios. Thus, although prediction paradigms can be used with both preschoolers and infants, the phenomenon offers no way of clarifying whether the two groups are using the same mechanisms. Moreover, the types of studies that have been marshaled in support of attributing conceptual knowledge to preschoolers have either not yet been done with infants (e.g., a large number of converging tests) or require peripheral linguistic skills well outside of infants' abilities (e.g., explanation tasks).

There are, perhaps, even more fundamental hurdles facing an "empirical typologies" account of infants' predictions in false belief scenarios. The empirical typologies that could support the kinds of predictions infants make in false belief scenarios would have to be fairly sophisticated, including generalizations such as those listed above, like "people look for things where they last put/saw them" or "people look for things where they told someone to put them." Where might these empirical typologies come from? We can assume that much of the human activity that infants see could provide the relevant data for such a system – after all, people do presumably act in empirically typical (usual) ways with rare exceptions (for instance, they look for things where they leave them). The key question is whether infants can extract the relevant generalizations from these data. In the next sections, we argue that the cognitive prerequisites for these skills are very likely in place for infants, likely from birth.

Sequential episodic encoding

Like other researchers in the field (e.g., Apperly & Butterfill, 2009; Perner & Ruffman, 2005) we would like to propose that young infants might be able to develop empirical typologies by relying on two basic perceptual and cognitive mechanisms that are sufficiently sophisticated

very early on in development: 1) Episodic encoding of intentional action that allows infants to parse an event representation into its constituent parts, and 2) statistical learning and generalization that allows infants to detect what kinds of intentional actions typically follow in sequence.

Episodic encoding of intentional action

To develop an empirical generalization such as "people look for things where they last put them," infants must first be able to encode actions and their constituent structure. That is, they must have some mechanism that allows them to identify intentional action (i.e., "put") and the constituent structure of that action. The constituent structure of action includes what we call the 4Ws of action: who, what, where, and when. If infants can do this sort of "episodic encoding", then they plausibly possess the ability to encode as a unit such bound events such as "*Ruby put her dress in the box last night"* and "*Ruby is searching for her dress in the box now."*

The proposal that young infants encode the constituent structure of action dovetails well with work in the field of infants' event memory (see Bauer, 2006). Although in verbal recall tasks, toddlers and young preschoolers sometimes have difficulties recounting past events, they typically perform well on tasks that rely on more implicit measures. In particular, constituent episodic encoding of intentional action can occur on a subconscious or implicit level (Dienes & Perner, 1999). That is, it may be possible to represent and store the 4Ws of a particular episode in a manner similar to a perceptual connectionist network, whereby the experience of the event changes in some small way the neural network dedicated to representing those experiences. The accrual of experiences that activate the same network over time are represented in the stabilization of the connection weights in the network. Over time, this registration would allow for detecting similarity and novelty along the constituent 4W dimensions.

Although there is now a significant amount of data suggesting that infants encode the

constituent characteristics of events (see Bauer, 2006, for a review), their abilities might be most

neatly described for the present purposes by taking a careful look at paradigms that investigate

young children's understanding of intentional action. For instance, in one task developed by

Woodward (1998), infants witnessed an actor repeatedly reach and grasp one of two toys until a

visual attention habituation criterion was met. Then, in test trials, infants as young as 6 months

dishabituated (i.e., showed longer looking) to a scene in which the person reached for and

grasped the other toy, suggesting that they detected the change in one of the Ws (the "what") that

was involved in the intentional action. A series of control studies showed that infants did not

dishabituate to the change in toy when there was no obvious person involved (i.e., no "who")

thereby suggesting that all 4Ws might be important for encoding episodic representations.

Further to this point, subsequent work has shown that when the familiarization episode is

followed by a test event in which a *new* person grabs for an object, infants dishabituated strongly

irrespective of which object the new person grabbed (Buresh & Woodward, 2007). These

findings suggest that even 6-month olds are sensitive to changes in any of the constituents of

intentional actions, a sensitivity that must be made possible by prior constituent encoding of

intentional action.[2]

Statistical learning and generalization

One straightforward way in which constituent episodic encoding can develop into a broad

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2 To those familiar with details of the seminal Woodward (1998) task, our claim may initially
seem counter-intuitive because the infant observers did not respond to the change of reach
position in test trials as long as the reach was to the goal object. However, the position change of
the goal object in this task likely would not constitute a change in the 'Where' constituent as the
new space on the stage shares the same boundaries. Actual changes in location of goal-directed
activity (e.g., changes in rooms) do appear to be recognized by infants by at least 10 months of
age (Sommerville & Crane, 2009).

predictive system is through statistical learning and generalization. Saffran and colleagues (Saffran, Aslin, & Newport, 1996) showed that infants could parse words out of a continuous speech stream through sensitivity to transitional probabilities. That is, infants judge syllables that have high transitional probabilities (i.e., syllables that usually occur in sequence) as constituting a coherent unit, whereas syllables that have low transitional probabilities (i.e., that occur in sequence only rarely) are not likely to constitute coherent units. The same kinds of skills have been shown in non-human primates as well (Hauser, Newport, & Aslin, 2001). Recently, Baldwin and colleagues showed that these same mechanisms work in the action domain (Baldwin, Anderson, Saffran, & Meyer, 2008); infants expect aspects of action (see e.g., Baldwin, Baird, Saylor, & Clark, 2001) that have high transitional probabilities to form coherent units. We suggest that the same system might be at work in helping children to discern patterns of contingent intentional action. That is, if infants notice that constituent-encoded events tend to follow one another in sequence (i.e., "Ruby put her dress in the box last night" and "Ruby is looking for her dress in the box this morning"), then children might be able to develop expectations about how intentional actions typically lead to one another.

Of course, for this system to be very powerful, it must develop general rather than specific rules. For instance, instead of encoding the specific events "Ruby put her dress in the box last night" and "Ruby is looking for her dress in the box this morning," the system would be better off coding these events in a more generalized algebraic structure (Marcus, 1999, 2001), such as "$[X_{agent}]$ put $[Y_{object}]$ at $[Z_{location}]$ in the past" which would then be followed by "$[X_{agent}]$ is looking for $[Y_{object}]$ at $[Z_{location}]$ now" where X, Y, and Z can be any agent, object, or location that remains the same across events. We do not know of any work that has investigated infants or children's abilities to extract this kind of algebraic structure. However, Marcus and colleagues

(Marcus et al., 1999) have shown that this type of generalized pattern representation occurs when 6-month-old infants process an ongoing speech stream, thereby making it plausible that a similar type of pattern detection could occur in the action domain (Baldwin & Baird, 2001). This kind of learning would be critical to establishing sensitivity to the kinds of patterns that a two system account suggests is operating when infants show surprise or predictive looking in the false belief paradigms.

Social cognition from sequential episodic encoding: Evidence from non-human species

To illustrate the potential power of sequential episodic encoding, we look to recent work with nonhuman animals. Some corvids, such as the Western Scrub Jay, are socially living, food-storing birds who are thus faced with the challenges of remembering both where their caches are and protecting their caches from thieves. A primary strategy that corvids use to protect their caches is "re-caching", that is, moving their food to another location when the original cache location was observed by a competitor. Work by Clayton and colleagues (e.g., Dally, Emery, & Clayton, 2006) has argued that constituent episodic encoding (i.e., encoding who, what, where, and when) allows scrub jays to engage in strategic re-caching (Dally, et al., 2006; Emery, Dally, & Clayton, 2004). In these studies, birds cached food in distinctive trays while observers in an adjoining cage looked on. When subsequently given the opportunity to recover food in private, jays re-cached food items more often if they had been previously observed by a dominant group member than if the observer had been a partner or a subordinate (Dally et al., 2006). A second experiment in this study presented scrub jays with two trays in which to cache, each witnessed by a different observer. When the jays were given the opportunity to recover the caches, one of the two observers was present. Subjects re-cached more items from the tray that this particular bird had previously observed than the tray observed by the other bird.

One might be tempted to assume that the re-caching behavior was a response to the subtle behaviors of an intimidating, competitive observer. That is, perhaps there are ways in which behavior changes once a bird knows where food is. Perhaps it is the sensitivity to these subtle cues (e.g., "evil eye") rather than the memory of the competitor being at the location that is driving behavior. Against this interpretation, Dally et al. (2006, 2009), showed that subject birds did not re-cache their stores in the presence of a competitor who instead of observing the subject bird's cache had seen another bird's caching activity. The authors argued that if re-caching was being motivated primarily by signals from the visible competitor bird, then subject birds would have demonstrated re-caching in both conditions. The study's findings thus confirm that it is the memory of the competitor's location at the time of the initial caching that affected re-caching behavior.

What was perhaps most intriguing about this study's findings was that deeper analyses showed that simply encoding the constituent structure events is not alone sufficient to promote re-caching behavior; re-caching was only carried out by older birds who had prior experience with pilfering (Dally et al., 2009; Emery & Clayton, 2005). These findings suggest that re-caching behavior depends on a learning mechanism that enables scrub jays to derive typical action sequences (i.e., what kinds of behaviors typically follow other behaviors). That is, corvids are able to combine their constituent encoding of events with a mechanism that allows them to derive and recognize statistically regular sequences of events, representations of which might drive behavior. Through these mechanisms, scrub jays might develop schema that allow them to expect sequences and combinations such as "Individuals look for food where they last saw it." For the corvids, recognizing this empirical typicality is powerful because it allows for the straightforward strategy of protecting the food by moving it to a location that has not been seen

by the competitor.

It seems possible that the same underlying mechanisms might account for the performance of non-human primates in similar situations. A full review of this literature is beyond the scope of this chapter, but some studies illustrate that non-human primates can be successful in cases where sequential episodic encoding can suffice, but not otherwise. For instance, while watching the hiding of a food item in one of two locations in an adjacent cage, a subordinate chimpanzee will encode whether a dominant chimpanzee has also observed the hiding event and later only attempt to retrieve the hidden food in conditions in which the dominant chimpanzee did not previously witness the hiding (Hare, Call, & Tomasello, 2002). As with the scrub jays, it seems sufficient to be sensitive to an empirical typicality like, "agents look for food where they last saw it." A key prediction made by this account is that if the scenario deviated much from this empirical typicality to the extent that the typicality could not be used to make appropriate predictions, then performance might fall apart. It seems as though this might be the case. At least two of such tasks may have been complicated by additional processing requirements; here, chimpanzees had to inhibit choosing the same hiding location of food that a misinformed experimenter previously chose (Call & Tomasello, 1999; Krachun, Carpenter, Call, & Tomasello, 2009).

Are there necessary connections between infants and preschoolers skills?

Apperly and Butterfill (2009) conceptualize the cognitive machinery used by infants a little differently and more subtly than we have here. Nonetheless, they make several points related to their characterization of the infant system that we believe would apply to our characterization of that system as well. Namely, Apperly and Butterfill noted that the system that infants use is

highly efficient and may even, at times, be used by adults to make quick predictions about others' actions in particular scenarios. There is plenty of evidence to suggest that adults regularly use behavioral typologies to make predictions about others' actions. For instance, Keysar and colleagues (e.g., Keysar, Lin, & Barr, 2003) have shown across several studies that adults' first, rapid guesses about the meanings of words (as detected through eye-tracking measures) are based more on empirical generalizations (how a speaker has used a word in the past) rather than complicated inferences about speakers' beliefs and intentions. Of course, it is not that adults cannot make such complicated inferences; it is only that they take time and may need to be invoked only when our more automatic processing results in a disrupted flow of communication (Kronmüller & Barr, 2007). Apperly and Butterfill (2009) take the position that because of their "job descriptions" over developmental time, the system that infants and adults use to make rapid predictions about others' behavior – based, we think, on generalized empirical models of what people typically do – is fundamentally dissimilar and discontinuous with the system that preschoolers and adults use to *explain* others' actions using theoretical representational constructs.

While we agree with Apperly and Butterfill (2009) that the systems are fundamentally dissimilar, we think it is important to note that there may be ways in which the development of preschoolers' theory of mind may be based on the empirical typologies that are developed early in life. For instance, it could be that emerging conscious awareness of empirical typologies support the development of abstract theoretical concepts that ultimately provide coherence to the empirical typologies (Karmiloff-Smith, 1994; Zelazo, 2004). There is now emerging evidence suggesting that young infants' performance in social cognitive paradigms is associated with preschoolers' theory of mind development more than 36 months later. For instance, infant

looking behavior in social cognitive tasks at 12 months of age (e.g., intention reading, disposition attribution) has been found to correlate with a battery of theory of mind tasks including false belief at 4 years (Wellman, Lopez-Duran, LaBounty, & Hamilton, 2008; Wellman, Phillips, Dunphy-Lelii, & LaLonde, 2004; Yamaguchi, Kuhlmeier, Wynn, & vanMarle, 2009). The important point is that the "continuities" that are shown across these studies may represent an intriguing developmental relation whereby the empirical typologies that support infant looking behavior in habituation and violation-of-expectation tasks also provide the best data for theory building. Yet, once established, engaging a theory of mind may work on its own cognitive substrate without borrowing from or relying on the persistent empirical typologies that at one time provided a foundation for the theory.

CONCLUSION

In the first half of our chapter, we argued that young preschoolers' failures on false belief tasks are unlikely to be due to domain-general performance limitations, namely, immature executive functioning. We argued this on two fronts. First, cross-cultural data showing that Chinese children with advanced executive functioning to *not* show equally advanced theory of mind performance relative to their North American counterparts. Second, EEG studies show that preschoolers' theory of mind performance is paced by maturational changes within brain areas that are associated with theory of mind reasoning in adults (i.e., MPFC and rTPJ), and not with areas that are associated with executive functioning. Thus, we argue that young preschoolers likely do not have a representational understanding of beliefs. This conclusion is at odds with claims from findings showing that, in looking paradigms (i.e., preferential looking, or predictive gaze), infants seem to have expectations that people will act in accordance with false beliefs. To

resolve this discrepancy, we propose, as others have, a "two system account" whereby infants' behavior in false-belief looking paradigms is supported by a cognitive-perceptual substrate other than a representational theory of mind. In particular, we propose that infants' and toddlers' expectations in looking-paradigm false belief tasks might be supported by empirical generalizations that are derived through sequential episodic encoding of human intentional action. We note also that these conjectures are difficult to test, but, counter to other claims in the literature, we believe that a "two system" account is both a necessary and plausible theoretical step in understanding the developmental trajectory of young children's theory of mind.

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Figure 1.

Standardized performance on a) Executive Functioning and b) False Belief Tasks in Chinese and North American preschoolers (from Sabbagh et al., 2006)
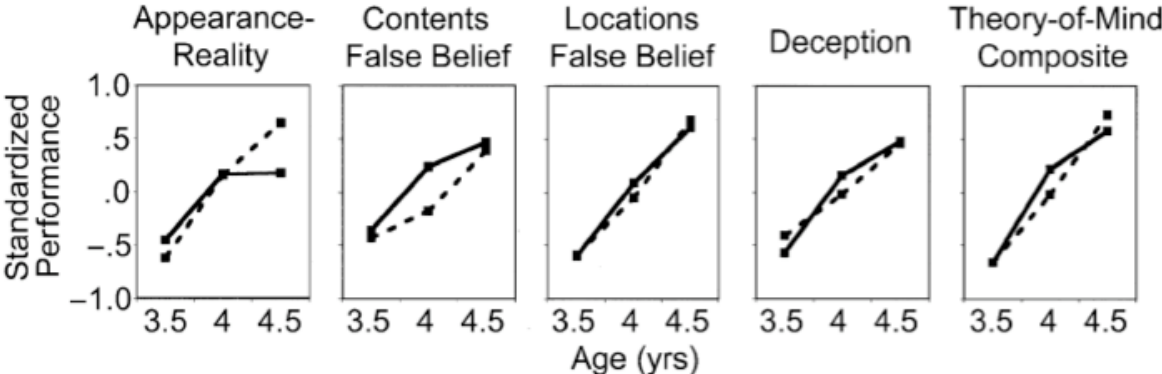
a)
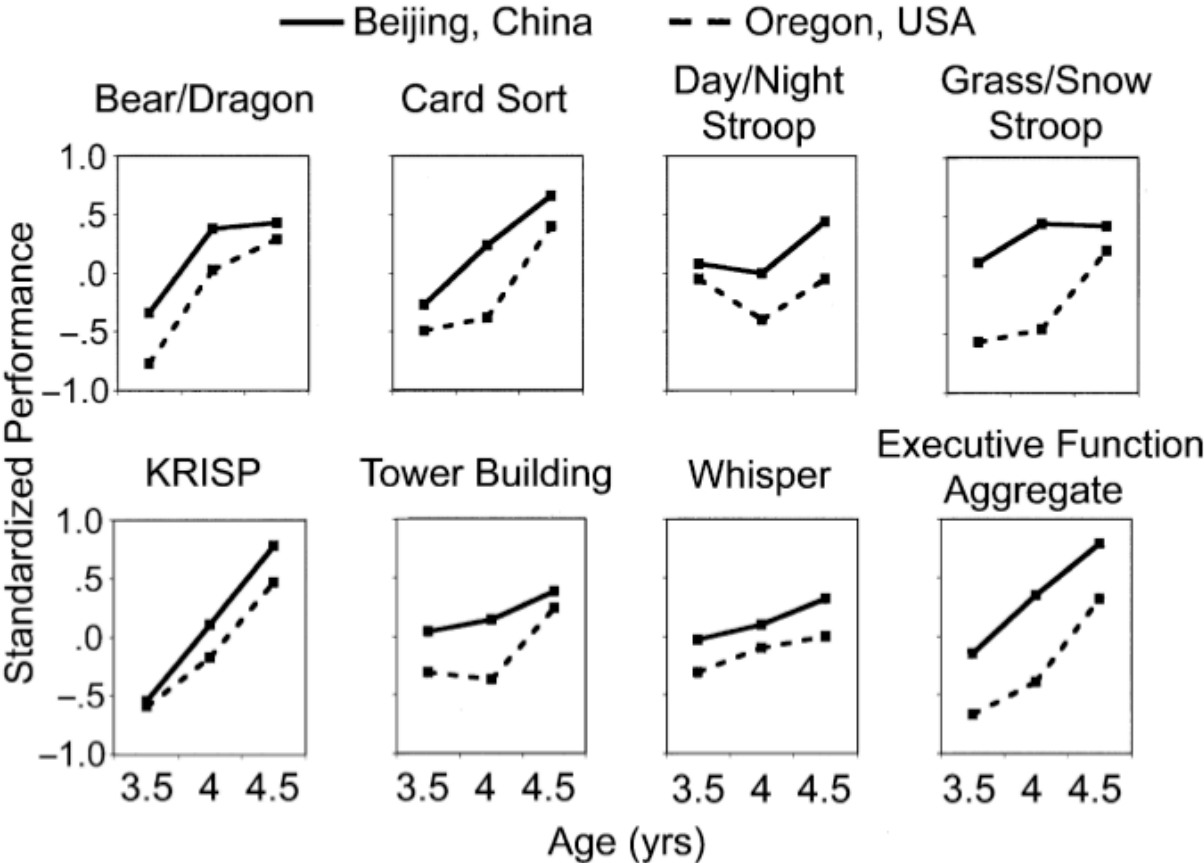
b)

Figure 2.

Overlap between the neurodevelopmental correlates of preschoolers' theory of mind and the regions that are typically activated in theory of mind tasks with adults (from Sabbagh et al., 2009).