PSYCHOLOGICAL REASONING IN INFANCY

Renée Baillargeon[1], Rose M. Scott[2], and Lin Bian[1]

[1]Department of Psychology, University of Illinois, Champaign, Illinois 61820; email: rbaillar@illinois.edu, linbian2@illinois.edu
[2]Psychological Sciences, University of California, Merced, California, 95343; email: rscott@ucmerced.edu

Citation
Baillargeon, R., Scott, R. M., & Bian, L. (2016). Psychological reasoning in infancy. *Annual Review of Psychology, 67*.

Keywords
infant cognition, psychological reasoning, theory of mind, rationality, agency, mental states, false beliefs, implicit reasoning

Abstract
Adults routinely make sense of others' actions by inferring the mental states that underlie these actions. Over the past two decades, developmental researchers have made significant advances in understanding the origins of this ability in infancy. This evidence indicates that when infants observe an agent act in a simple scene, they infer the agent's mental states and then use these mental states, together with a principle of rationality (and its corollaries of efficiency and consistency), to predict and interpret the agent's subsequent actions and to guide their own actions toward the agent. In this review, we first describe the initial demonstrations of infants' sensitivity to the efficiency and consistency principles. We then examine how infants identify novel entities as agents. Next, we summarize what is known about infants' ability to reason about agents' motivational, epistemic, and counterfactual states. Finally, we consider alternative interpretations of these findings and discuss the current controversy about the relation between implicit and explicit psychological reasoning.

Contents

INTRODUCTION

Over the past two decades, numerous reports have presented evidence that psychological reasoning, the ability to make sense of agents' intentional actions, emerges early in infancy (0-2 years of age). This evidence supports the *mentalistic* view that human infants are born equipped with a psychological-reasoning system that provides them with a skeletal explanatory framework for reasoning and learning about agents' actions (e.g., Baillargeon et al. 2015; Baron-Cohen 1995; Johnson 2005; Leslie, 1994; Premack & Premack 1995; Scott et al. 2015b; Spelke & Kinzler 2007). When infants observe an agent act in a simple scene, their psychological-reasoning system enables them (a) to infer the mental states that underlie the agent's actions and (b) to use these mental states, together with a principle of *rationality*, to predict and interpret the agent's subsequent actions and to guide their own actions toward the agent. The rationality principle dictates that, all other things being equal, agents will act rationally; corollaries of the principle include *efficiency* (agents will expend as little effort as possible to achieve their goals) and *consistency* (agents will act in a manner consistent with their mental states) (e.g., Baillargeon et al. 2015; Dennett 1987; Gergely et al. 1995).

In our review, we first describe the initial demonstrations of infants' sensitivity to the efficiency and consistency principles. We then examine how infants identify novel entities as agents. Next, we summarize what is known about infants' ability to reason about agents' motivational states (e.g., goals and dispositions), epistemic states (e.g., knowledge and ignorance), and counterfactual states (e.g., false beliefs and pretense). Finally, we consider alternative interpretations of these results and discuss the current controversy about the relation between implicit and explicit psychological reasoning. In the limited space available, we could not include recent findings on infants' sociomoral reasoning (for reviews, see Baillargeon et al.

2014, 2015; Bloom 2013; Hamlin 2013). Nevertheless, it should be stressed that these findings provide additional support for those reviewed here: infants could not predict or evaluate social interactions among novel entities without first identifying these entities as agents and determining what goals they are pursuing and what information is available to them (e.g., Hamlin et al. 2007; Johnson et al. 2010; Meristo & Surian 2013; Sloane et al. 2012). Our review highlights these foundational psychological-reasoning building blocks.

THE RATIONALITY PRINCIPLE

The initial investigations to address (implicitly or explicitly) infants' sensitivity to the rationality principle used the violation-of-expectation method, a prevalent looking-time method that takes advantage of infants' natural tendency to look longer at events that violate, as opposed to confirm, their current expectations (e.g., Luo & Baillargeon 2005b; Stahl & Feigenson 2015; Wang et al. 2004).

Efficiency

The first demonstration that infants are sensitive to the efficiency principle came from experiments by Gergely and Csibra using a novel *detour* task (e.g., Csibra 2008; Csibra et al. 2003; Gergely et al. 1995). Infants ages 6—12 months first received familiarization trials in which an agent had to move around or over an obstacle to reach a target. In the test trials, the obstacle was removed, and the agent travelled to the target either in a straight line (new-path event) or along the same detour path as before (old-path event). Infants looked reliably longer at the old-path than at the new-path event, suggesting that they (a) attributed to the agent the goal of reaching the target and (b) expected the agent to pursue this goal efficiently, in accordance with the efficiency principle: with the obstacle removed, a more efficient path to the target became possible, and infants detected a violation when the agent ignored this shorter path and followed the same path as before. These conclusions were supported by a control condition identical to the experimental condition except that in the familiarization trials the obstacle stood behind the agent and thus no longer blocked access to the target; nevertheless, the agent used the same detour path as in the experimental condition. Infants looked about equally at the two test events, suggesting that they could not generate a rational explanation for the agent's behavior in the familiarization trials (i.e., why did the agent detour en route to the target?), and they therefore held no expectation about the agent's actions in the test trials. These findings have been replicated in many laboratories (e.g., Brandone & Wellman 2009; Kamewari et al. 2005; Sodian et al. 2004).

Additional investigations indicated that infants expect efficiency not only in the length of the path used to reach a target (they expect a shorter as opposed to a longer path), but also in the number of actions performed to obtain an object (they expect a shorter as opposed to a longer means-end action sequence; e.g., Scott & Baillargeon 2013; Southgate et al. 2008). Finally, infants consider mental as well as physical effort in judging efficiency (Scott & Baillargeon 2013). In an experiment with 16-month-olds, an agent saw an experimenter cover two identical toys with a transparent and an opaque cover (a small screen then hid the transparent cover from the infants, so that neither toy was visible to them). Although both toys were physically equally accessible to the agent, infants expected her to reach for the toy that was visible to her and hence mentally more accessible. Together, these results indicate that infants' understanding of efficiency is highly abstract and encompasses both physical and mental effort.

Consistency

The first demonstration that infants are sensitive to the consistency principle came from experiments by Woodward using a novel *preference* task (e.g., Woodward 1998, 1999). Infants ages 5—12 months first received familiarization trials in which an agent faced two different objects, object-A and object-B; in each trial, the agent reached for and grasped object-A. In the test trials, the objects' positions were switched, and the agent reached for either object-A (old-object event) or object-B (new-object event). Infants looked reliably longer at the new-object than at the old-object event, suggesting that they (a) attributed to the agent a preference or liking for object-A, as the agent always chose it over object-B, and (b) expected the agent to continue acting on this preference in the test trials, in accordance with the consistency principle. This finding has been replicated in many laboratories (e.g., Luo & Baillargeon 2005a; Martin et al. 2012; Spaepen & Spelke 2007).

Subsequent investigations introduced two variations of the preference task that reinforced its conclusions. In one variation, only object-A was present in the familiarization trials; object-B was not added until the test trials (e.g., Bíró et al. 2011; Luo & Baillargeon 2005a; Song et al. 2014). Infants now looked equally at the two test events: because no choice information was available in the familiarization trials, infants had no basis for gauging the agent's disposition toward object-A (i.e., did the agent reach for it because of a positive disposition toward it or because it was the only object present?); as a result, infants could form no expectation about which object the agent would choose in the test trials. The other variation was identical to the original preference task except that new object-C replaced object-B in the test trials (e.g., Bian & Baillargeon in prep.; Robson & Kuhlmeier 2013). Infants looked longer at the new- than at the old-object event, and this effect was eliminated when only object-A was present in the familiarization trials. Thus, when the agent repeatedly chose object-A over object-B, infants attributed to the agent an enduring positive disposition toward object-A, and they expected this disposition to be maintained even in the presence of a new object.

Consistency Trumps Efficiency

When efficiency and consistency are pitted against one another, infants expect consistency to prevail. After an agent demonstrates a preference for object-A over object-B in the familiarization trials, infants expect the agent to reach for object-A in the test trials even when physical constraints are added so that a longer, more effortful means-end action sequence is required to retrieve it than object-B (Scott & Baillargeon 2013). Infants thus expect consistency to trump efficiency, at least in situations where the effort required to obtain a preferred object is not much greater than that required to obtain a non-preferred object.

IDENTIFYING AGENTS

The findings summarized in the preceding section indicate that infants in the first year of life are already capable of sophisticated psychological reasoning about agents' actions. But whom do infants view as agents? Do infants initially interpret the actions of only human agents and gradually extend their action understanding to non-human agents? Or do infants reason from an early age about the actions of non-human agents? The available evidence supports the latter possibility: positive results have been obtained using non-human agents (e.g., boxes and geometric shapes) with infants as young as 3—6 months (a) in detour, preference, and other psychological-reasoning tasks (e.g., Csibra 2008; Luo 2011b; Schlottmann & Ray 2010) and (b) in sociomoral-reasoning tasks (e.g., Hamlin et al. 2007, 2010; Hamlin & Wynn 2011). These findings naturally raise the question of how infants identify novel non-human entities as agents.

Internal Control

One early hypothesis about how infants identify novel agents involved self-propulsion: perhaps any entity that can move on its own is viewed as agentive (e.g., Baron-Cohen 1995; Leslie, 1994; Premack 1990). In time, however, it became clear that this hypothesis was incorrect. Instead, infants seem to identify a novel entity as an agent if it gives sufficient evidence that it has internal control over its actions (i.e., that it chooses when and how to act). This evidence can come in a variety of guises.

Detecting and responding purposely to changes. When a change occurs in a scene, a novel entity is categorized as an agent if it gives evidence that it detects this change and responds to it in a goal-directed manner (an action is goal-directed if it is performed to achieve a particular outcome, such as a communicative or an instrumental outcome). In a series of experiments, Johnson and her colleagues (Johnson et al. 2007b; Shimizu & Johnson 2004) tested 12-month-olds using a preference task in which the “agent” was an oval entity covered with green fiberfill. When the entity simply approached and rested against object-A in the familiarization trials, infants did not view the entity as agentive and looked equally at the new- and old-object test events (making clear that self-propulsion alone does not constitute evidence of agency, nor does repeating a single, fixed action that could be described as goal-directed). Positive results were obtained, however, if the entity first interacted with an experimenter in a “conversation”: the experimenter spoke in English and the entity responded with varying beeps. Because the entity gave evidence that it detected and responded purposely to the experimenter’s utterances (as though pursuing a communicative goal), infants perceived it as agentive. Additional results indicated that infants did not view the entity as an agent if (a) the experimenter spoke but the entity remained silent (suggesting that it was not merely seeing the experimenter talk to the entity that led infants to view it as agentive) or (b) if the entity beeped but the experimenter remained silent (suggesting that it was not merely observing the entity produce varying beeps that led infants to view it as an agent; variable self-generated behavior, if it appears random, does not constitute evidence of agency). In converging experiments using an attention-following task, Johnson et al. (2008) found that after observing the oval entity turn toward one of two targets, 14—15-month-olds turned in the same direction if the entity first conversed with an experimenter (agent condition) but not if it beeped and the experimenter remained silent (non-agent condition).

The preceding results have been replicated and extended in other laboratories (e.g., Beier & Carey 2014; Deligianni et al. 2011). In one attention-following task, for example, 12—13-month-olds perceived a rounded brown entity as agentive if it responded with beeps when the experimenter clapped his hands playfully toward it, but not if it first responded with beeps when the experimenter clapped two sticks toward it with a neutral expression (Beier & Carey 2014). This negative result suggests that mere turn-taking does not provide sufficient evidence for agency: the entity must demonstrate that it can not only detect events in its environment, but also respond to them in a goal-directed manner, as when participating in a conversation or a playful interaction. When the experimenter clapped sticks and the entity beeped in response, infants were unable to interpret its actions as goal-directed, and they therefore did not identify it as an agent.

In the preceding experiments, the novel entity interacted with a human experimenter; in other experiments, no experimenter was involved, and infants viewed the entity as agentive if it gave evidence that it detected and responded purposely to changes in the scene (e.g., the introduction of objects, a change to the size of an obstacle, or the approach of another entity; Bíró et al. 2007; Hernik & Southgate 2012; Luo & Baillargeon 2005a; Schlottmann et al. 2012). In one preference task, for example, 5-month-olds first saw a box move back and forth at the center of an apparatus (Luo & Baillargeon 2005a). Next, object-A and object-B were added, and the box approached and rested against object-A. Infants interpreted the change in the box's behavior as evidence that it was agentive; as a result, they attributed to the box a preference for object-A, and they looked longer when it approached object-B in the test trials. Interestingly, this effect was eliminated if a long handle was attached to the box, with the end of the handle protruding through the sidewall of the apparatus; it was then unclear whether the box had autonomous control over its actions, and infants no longer viewed it as an agent.

Choosing goals or means. When no change occurs in a scene, infants may still perceive a novel entity as agentive if it gives evidence that it is choosing either which target to approach or which (efficient) path to follow to a target. In preference tasks, 6- and 12-month-olds viewed a novel entity as agentive (as evidenced by their looking longer at the new-object event in the test trials) if it "turned" toward object-A before approaching it in the familiarization trials, as though choosing it as its goal object (Johnson et al. 2007b; Schlottmann & Ray 2010). In a detour task, Csibra (2008) familiarized 6-month-olds with an event in which a box had to move around an obstacle to reach a target. Infants viewed the box as agentive (as evidenced by their looking longer at the old-path event in the test trials) if it detoured randomly around the left or the right side of the obstacle across the familiarization trials, as though choosing its path in each trial. In contrast, infants did not identify the box as an agent if it approached the target using the same fixed path around the obstacle in every familiarization trial. This negative result provides further evidence that for infants, self-propulsion and the repeated production of a single, fixed action that could be described as goal-directed do not provide sufficient evidence for agency (from an adult perspective, a mechanical device such as a ceiling fan would show these same abilities).

Self-Propelled Objects, Agents, and Animals

Although self-propulsion is not sufficient for infants to identify a novel entity as an agent, it could still be necessary for them to do so. Are infants able to view inert objects as agents, as adults are (e.g., the Magic Mirror in the Snow White fairy-tale)? This question has received little experimental attention to date, but preliminary evidence suggests that infants identify an inert object as an agent if it demonstrates autonomous control over its communications (e.g., if it beeps when object-A, but not object-B, is revealed; Baillargeon et al. 2009). This initial evidence, paired with the results reviewed in the preceding section and additional findings on infants' expectations about self-propelled objects and animals (e.g., Baillargeon et al. 2009; Leslie 1994; Luo et al. 2009; Newman et al. 2008; Setoh et al. 2013), suggests three conclusions. First, self-propulsion and agency are distinct concepts for infants: an object may be self-propelled without being agentive, and it may be agentive without being self-propelled. A self-propelled object has an internal source of physical energy that allows it to exert or resist physical forces; an agentive object has mental states that give it control over its actions. Second, objects that are both self-propelled and agentive are categorized as animals and endowed with additional, biological properties such as innards. In a series of experiments, 8-month-olds detected a violation when a novel entity that was both self-propelled and agentive was revealed to be hollow, but they detected no such violation when the entity was only self-propelled, only agentive, or neither self-propelled nor agentive (Setoh et al. 2013). Third, these various results suggest that at least three core causal-reasoning systems (and their associated concepts) operate seamlessly to guide infants' responses to novel entities: the physical-reasoning system (energy), the psychological-reasoning system (mental states), and the biological-reasoning system (innards). As Keil (1995) emphasized, these early abstract causal understandings are very shallow and divorced of all mechanistic detail; nevertheless, they play a critical role in orienting infants to construe entities and their causal powers effectively.

Predictive Cues

We have seen that infants identify a novel entity as an agent if it gives evidence of internal control over its actions. This identification process may be relatively slow, however, so it makes sense that infants would also use their discrimination and categorization abilities to learn which perceptual cues predict agency.

Because most of the agentive entities infants encounter in daily life are humans and non-human animals (henceforth animals), predictive cues for agency will include motion cues (e.g., biological motion), morphological cues (e.g., having a face, a humanoid form, or a four-legged form), and surface-texture cues (e.g., having fur). Not surprisingly, given their intense interest in humans and animals (e.g., LoBue et al. 2013), infants rapidly begin to learn these cues and to use them in identifying novel agents (e.g., Arterberry & Bornstein 2002; Johnson et al. 2001; Kamewari et al. 2005; Träuble & Pauen 2011; Setoh et al. 2013; Yoon & Johnson 2009). In a detour task, for example, 6.5-month-olds identified a humanoid robot as an agent even though it followed the same fixed path around the obstacle in each familiarization trial (Kamewari et al. 2005). Similarly, in attention-following tasks, 12-month-olds turned in the same direction as a point-light human in an upright position (Yoon & Johnson 2009) or as a novel rounded entity with a face and fur (Johnson et al. 2001).

ATTRIBUTING MOTIVATIONAL STATES

The initial findings of Gergely, Csibra, and Woodward (reviewed earlier) indicated that infants can attribute to agents motivational states such as goals and dispositions. Subsequent research has extended these findings in several directions, as summarized below.

Goals

By their first birthday, infants can infer a variety of goals including: inspecting, reaching, obtaining, or displacing an object; comforting, helping, hindering, chasing, or hitting an agent;

and giving a toy to an agent or stealing a toy from an agent (Csibra et al. 2003; Hamlin & Wynn 2011; Johnson et al. 2007a, 2010; Király et al. 2003; Kuhlmeier et al. 2003; Luo & Baillargeon 2005a; Premack & Premack, 1997; Woodward 1998). Moreover, infants understand not only single goal-directed actions, but also more complex means-end action sequences. In a preference task with 12-month-olds, for example, object-A and object-B rested inside separate containers, and in each familiarization trial the agent opened object-A's container in order to retrieve it (Woodward & Sommerville 2000). In the test trials, the objects switched containers, and the agent grasped either the old (old-container event) or the new (new-container event) container and paused. Infants looked longer at the old- than at the new-container event, suggesting that they attributed to the agent a preference for object-A and understood that her intermediate actions on its container merely served her overarching goal of obtaining object-A. As was found in detour tasks, infants demonstrated sensitivity to the efficiency principle in their interpretations of the agent's means-end actions: if object-A stood next to (as opposed to inside) its container in the familiarization trials, infants could no longer make sense of the agent's inefficient actions (i.e., why did she first open the container next to object-A?), and they held no expectation about her actions in the test trials (see also Bíró et al. 2011).

Infants also demonstrate their ability to identify goals in imitation tasks. For example, infants are more likely to imitate actions that are marked as intentional ("There!") than actions that are marked as accidental ("Woops!) (e.g., Carpenter et al. 1998; Olineck & Poulin-Dubois 2005); they are equally likely to reproduce intended outcomes after watching successful or incomplete demonstrations (e.g., Meltzoff 1995; Olineck & Poulin-Dubois 2009); and they are more likely to reproduce goal-relevant than goal-irrelevant action components (e.g., Brugger et al. 2007; Carpenter et al. 2005).

Although infants can understand a variety of goals, there are of course situations where they will fail to identify an agent's particular goal, for a variety of reasons. In some cases, infants may simply lack the relevant knowledge to infer the goal of a novel action. We can easily imagine that infants may be nonplussed when they first observe a parent listen to a cell phone, point a remote key at a car, or lick a fingertip before turning a page; infants may appreciate that the parent is acting purposely, but be uncertain about what outcomes these actions are meant to achieve. In line with this analysis, 9-month-olds failed at a preference task in which an agent placed the back of her hand against object-A in the familiarization trials, instead of grasping it; because infants could not infer the goal of this baffling back-of-hand action, they looked equally at the new- and old-object events (Woodward, 1999). Several investigations have taken advantage of this negative result to examine what experiences might lead infants to view the back-of-hand action as goal-directed (e.g., Bíró et al. 2014; Király et al. 2003; for similar investigations with other novel actions, e.g., Gerson & Woodward 2012, 2013). In one experiment, for example, an experimenter and 12-month-olds first took turns lifting Velcro-covered blocks using a Velcro band worn on the back of their hands (Bíró et al. 2014). After this training session, infants received a preference task in which an agent wearing a similar Velcro band produced back-of-hand actions, without lifting the objects. Results were positive, suggesting that the training session helped infants view the agent's back-of-hand actions as goal-directed; as a result, infants attributed to the agent a preference for the object she repeatedly chose, and they expected her to maintain this preference in the test trials, in accordance with the consistency principle.

In other cases, infants may possess the relevant knowledge to identify an agent's goal, but have difficulty doing so because the scene does not provide sufficient information to guide or support their reasoning. In one imitation task, for example, 16-month-olds first watched an experimenter demonstrate the use of a novel T-shaped rake to retrieve a toy out of reach (Esseily et al. 2013). When encouraged to do the same, infants showed some success only if the experimenter had first made clear the goal of her actions by stretching her arm and hand toward the out-of-reach toy, as though vainly trying to grasp it. In other investigations, 3-month-olds succeeded at detour and preference tasks only if they were first primed to focus on the goal of the agent's actions (e.g., Skerry et al. 2013; Sommerville et al. 2005). In one investigation, for example, infants in the experimental condition first received a brief play session in which they wore Velcro mittens (adapted from Needham et al. 2002) that allowed them to pick up Velcro-covered toys by swiping at them (Skerry et al. 2013). Next, infants received a detour task involving videotaped events: in the familiarization trials, an agent wearing a similar Velcro mitten reached over a barrier to get a toy and then paused; in the test trials, the barrier was removed and the agent reached for the toy either in a straight line (new-path event) or using the same arching action as before (old-path event). Infants looked longer at the old- than at the new-path event; in contrast, infants who wore mittens without Velcro during the play session, or who did not receive a play session, looked about equally at the two events. Together, these results suggest that the experimental play session, where swipes brought about observable outcomes, helped infants focus on and extract the goal of the agent's actions in the detour task. Once infants had identified this goal, they expected the agent to pursue it efficiently, in accordance with the efficiency principle. Although the young infants in this experiment were unable to focus on the agent's goal without an appropriate priming experience (see also Gerson & Woodward 2014; Sommerville et al. 2005), it is unlikely that such an experience is always necessary, as positive results have been obtained with 3-month-olds in tasks involving richer or less minimal actions (e.g., Hamlin et al. 2010; Luo 2011b).

Finally, in situations where infants succeed in identifying an agent's goal, they expect the agent's subsequent actions to abide not only by the efficiency principle, as we have seen, but also by the consistency principle. First, infants detect a violation if an agent changes goal for no apparent reason. Thus, after watching familiarization trials in which a large circle chased a small circle in a scene, 12-month-olds detected a consistency violation in the test trials if the large circle caught up with the small circle and continued moving past it, as though ignoring it, instead of stopping against it (Csibra et al. 2003). Second, infants detect a violation if an agent shows an inappropriate emotional reaction following the attainment of a goal (Skerry & Spelke 2014). After watching a circle successfully jump over an obstacle to reach a target, 8- and 10-month-olds detected a consistency violation if the circle displayed a negative emotional reaction (frowning, crying, and rocking) as opposed to a positive emotional reaction (smiling, giggling, and bouncing).

Preferences

Modifications of the preference task have yielded many additional insights into infants' ability to attribute preferences. First, when watching an agent repeatedly choose object-A over object-B in the familiarization trials, infants attribute to the agent not simply a preference for that object in particular, but rather a preference for that object category in general (Spaepen & Spelke 2007). Thus, after seeing an agent repeatedly choose a black female doll over an orange dump truck (or the reverse), 12-month-olds attributed to the agent a preference for dolls (or trucks), and they expected the agent to reach for the toy from the preferred category even when new toys (a white male doll and a red tow truck) were used in the test trials.

Second, infants can use not only unvarying-choice information (i.e., the agent always chooses object-A over object-B), but also other types of information to attribute a preference to an agent. One type is *emotional* information: if an agent emotes positively toward one toy but negatively toward another toy, infants attribute to the agent a preference for the first toy (e.g., Barna & Legerstee 2005; Egyed et al. 2013). Another type is *statistical* information: if an agent chooses only toy ducks from a box that contains mostly toy frogs, infants infer that the agent prefers the ducks (e.g., Gweon et al. 2010; Kushnir et al. 2010). Yet another type is *effort* information: if an agent faces a single toy but has to go to some effort to obtain it in each familiarization trial (e.g., has to open a container or detour around an obstacle to retrieve it), infants conclude that the agent must have a positive disposition toward the toy. As might be expected, only rational effort matters: infants do not attribute a positive disposition if the agent's effortful actions are inefficient because the toy stands next to the container or the detour is wider than necessary (e.g., Bíró et al. 2011; Hernik & Southgate 2012). A final type of information, *equifinality* information, may constitute a special case of effort information: if an agent faces a single toy and approaches it in every familiarization trial even though the toy's position keeps changing (suggesting that the agent is willing to adjust its actions as needed to contact the toy), infants again conclude that the agent has a liking for the toy (Luo 2011b).

Third, infants recognize that preferences are attributes of individual agents: Mommy prefers white wine, but daddy prefers beer; big sister Jane is fond of sports, but big brother Karl likes videogames. Thus, after watching familiarization trials in which agent-A demonstrates a preference for object-A over object-B, infants age 9 months and older hold no expectation about which of the two objects a new agent, agent-B, will prefer (e.g., Buresh & Woodward 2007; Henderson & Woodward 2012). An important exception is that infants do generalize preferences demonstrated in "pedagogical" contexts to other agents (Csibra & Gergely 2009). In an experiment with 18-month-olds (Egyed et al. 2013), agent-A emoted positively toward object-A and negatively toward object-B, and then she left the room. Next, agent-B arrived and asked the infants to give her one of the objects. If agent-A used ostensive-communicative signals (e.g., looked at, smiled at, and greeted the infants) before and during her emotional displays, infants (a) interpreted these displays as pedagogical encounters aimed at teaching them the properties of the objects, (b) inferred that object-A was pleasing but object-B was not, and (c) expected agent-B to share the same knowledge and preference and so gave her object-A.

Fourth, in addition to preferences for objects (e.g., dolls), infants can attribute other types of preferences to agents. One type involves preferences for particular *activities*. After seeing an agent slide different objects, one at a time, forward and backward on an apparatus floor, 9- and 13-month-olds attributed to the agent a predilection for sliding objects, and they expected the agent to select a "slidable" over an "unslidable" object in the test trials (Song & Baillargeon 2007; Song et al. 2005). Another type of preference is for particular *colors*. After seeing that an agent preferred a red toy pepper over a black cup, and a red toy pyramid over a yellow toy house, 16-month-olds attributed to the agent a preference for red objects, and they expected the agent to select a new red object over a new green object in the test trials (Luo & Beck 2010). In recent experiments, 16-month-olds failed to attribute a color preference to an agent who consistently reached for a red football over a yellow football, no doubt because both toys belonged to the same object category (Mou et al. 2014). However, if infants saw the agent choose the red football over the yellow football in three familiarization trials, and then they saw the agent choose the yellow football over a green football in the next three familiarization trials, they concluded that the agent had an ordered set of preferences, and they expected the agent to prefer the red football over the green football when presented with both in the test trials.

Emotional States

To date, there has been little attention to the question of whether infants understand that emotions and moods, like goals and dispositions, can motivate agents' actions in a scene. As adults, we readily understand that an angry boy may kick rocks in his path or that a teenager looking forward to a date may sing happily in the shower. At what age do infants begin to understand that emotions may motivate (as opposed to simply accompany) actions? Such understanding appears to be present at least by the second year of life (Hepach & Westermann 2013). In one experiment, 14-month-olds saw two agents who were at times angry or happy perform actions that were either congruent or incongruent with their current moods. Infants showed greater sympathetic activity (as measured by pupil dilation) when an agent in an angry mood gently patted a toy or when an agent in a happy mood hit the toy.

Predicting Others' Actions

As evidence steadily accumulated that infants could infer agents' motivational states, researchers began to ask whether infants could use these states not only to interpret but also to predict agents' actions (e.g., Henrichs et al. 2014; Hunnius & Bekkering 2010; Kanakogi & Itakura 2011). As Brandone et al. (2014) stated, "a *prospective* intentional stance is fundamental to interpreting actions in real-time social situations and thus to interacting seamlessly with others" (p. 23).

The use of eye-tracking methodology has made it possible to examine in great detail under what conditions infants produce predictive looks that reflect their understanding of agents' motivational states. With this methodology, infants have been found to correctly anticipate agents' actions in detour tasks (e.g., Bíró 2013) and in preference tasks (e.g., Cannon & Woodward 2012; Kim & Song 2015). In one preference task, for example, 11-month-olds received four trials, each of which had three phases involving different movie clips (Cannon & Woodward 2012). In the familiarization phase, object-A and object-B rested in the top and bottom right corners of the monitor; a hand entered from the left, moved straight across the scene, and deflected just past midline to grasp object-A. This event was repeated three times. In the next phase, the object's positions were switched. In the test phase, the hand moved as before but paused just past midline. Infants were more likely to make their first look from the hand to object-A, suggesting that they attributed to the agent a preference for this object and anticipated that the agent would reach for it again.

Analyses of infants' brain activity during preference tasks also provide evidence of predictive psychological reasoning (Southgate & Begus 2013). In one experiment, 9-month-olds watched videotaped events while their sensorimotor-cortex activation was measured using electroencephalography (EEG). Infants first received familiarization trials in which an agent's hand consistently reached for and grasped object-A as opposed to object-B. Next, infants received several test trials; each included a baseline period (a moving screensaver) and a static anticipatory period in which either object-A or object-B was present and the hand rested in front of it. Comparison of the baseline and static periods showed greater motor activation during the test trials involving object-A. Thus, infants anticipated that the agent would reach when preferred object-A was present, but they showed no such anticipation when object-B was present.

Making Sense of Irrational Actions

We have seen that when an agent produces irrational actions (e.g., makes an unnecessary detour while approaching a target or opens a container before grasping a toy next to it), infants hold no expectation about the agent's subsequent actions. But are there situations where infants succeed in generating explanations for apparently irrational actions? Research on this question has focused on pedagogical cues and situational constraints.

Pedagogical cues. Infants interpret inefficient actions differently when accompanied by pedagogical signals. Király et al. (2013) built on a puzzling finding from an imitation task by Meltzoff (1988): after watching a model activate a light-box by touching it with his forehead, 14-month-olds were more likely to reproduce this action one week later than were control infants. Why did the infants imitate this inefficient head action, instead of using the more efficient approach of touching the light-box with their hands? Király et al. speculated that the ostensive-communicative cues that accompanied the model's demonstrations signaled to the infants that he was attempting to teach them the conventional use of this novel object. To examine this speculation, Király et al. tested 14-month-olds in two conditions. In the communicative condition, a model provided ostensive-communicative signals (e.g., she looked at and spoke to the infants) before and between her head actions on the light-box. In the non-communicative condition, the model performed the same demonstrations without interacting with the infants. After a 10-minute delay, infants in both conditions were presented with the light-box for 20 s. Although all infants first used their hands to activate the light-box, 65% of the infants in the communicative condition also attempted at least once to perform the head action (this effect was replicated in another experiment with a one-week delay); in contrast, only 29% of the infants in the non-communicative condition did so. The authors concluded that the head action, when accompanied by pedagogical cues, was "learned as a culturally relevant novel instrumental means that ought to be used to operate the novel artifact" (p. 482).

Situational constraints. Infants make use of situational constraints to generate explanations for actions that would otherwise violate the efficiency principle. In another imitation task with a light-box, Gergely et al. (2002) found that 14-month-olds were less likely to reproduce a model's head action one week later if her hands were occupied during the demonstration (the model wrapped herself in a blanket which she held with both hands) than if her hands were free (the model wore the blanket loosely and laid her hands on either side of the light-box). Infants thus attended to the constraints affecting the model's actions: when her hands were occupied, they interpreted her inefficient head action simply as an expedient, alternative means of activating the light-box. Similar results have been obtained in other laboratories (e.g., Paulus et al. 2011; Pinkham & Jaswal 2011; Schwier et al. 2006).

Infants also attend to situational constraints to make sense of actions that appear to violate the consistency principle. Luo (2010) built on a puzzling finding from a preference task by Woodward (2003): when an agent simply looked intently at object-A (as opposed to object-B) in the familiarization trials, without grasping it, 12-month-olds still succeeded in attributing to the agent a preference for object-A, but 7- and 9-month-olds did not (i.e., they looked equally at the new- and old-object test events). One possible interpretation of this negative result was that the younger infants detected a consistency violation: if the agent wanted object-A, as her attentional behavior suggested, why did she not take it, since it was within her reach and there was no obstacle in her way? In line with this interpretation, Luo found that 8-month-olds succeeded in attributing a preference for object-A to the agent if the scene was modified to provide an explanation for her failure to reach: either her hands were occupied holding the two handles of a sippy cup or she sat behind a small window that only allowed her to look at the objects. These results suggest that whereas 8-month-olds are in the habit of reaching for interesting objects within easy reach and interpret others' actions accordingly, 12-month-olds have learned (perhaps via parental admonitions during their expanding locomotor forays) that one may sometimes look at, but not touch, interesting objects.

ATTRIBUTING EPISTEMIC STATES

When interpreting an agent's actions in a scene, do infants consider not only the agent's motivation, but also the knowledge the agent possesses or lacks about the scene? To address this question, researchers have explored infants' ability to reason about epistemic states such as knowledge and ignorance. A critical issue has been whether infants (a) are fundamentally egocentric and as such incapable of attributing to an agent a representation of a scene that differs from their own or (b) are non-egocentric and able to recognize, at least in some situations, that an agent's knowledge about a scene may be less complete than their own.

Keeping Track of What Objects Agents Can See or Have Seen

Do infants attend to what objects an agent can or cannot see, and has or has not seen, and expect the agent to know about the seen objects but to be ignorant about the unseen objects? To shed light on these questions, several experiments have used preference tasks in which object-B is hidden from the agent—but not the infants—during the familiarization trials; the rationale is that if infants realize that the agent can see object-A but not object-B, they should perform as infants typically do when only object-A is present in the familiarization trials (Kim & Song 2015; Luo & Baillargeon 2007; Luo & Johnson 2009). In one experiment, 12-month-olds were assigned to an ignorance or a knowledge condition (Luo & Baillargeon 2007). In the familiarization trials of the ignorance condition, the agent sat centered behind a transparent screen and an opaque screen; object-A stood in front of the transparent screen, and object-B stood in front of the opaque screen (object-B was thus visible to the infants but not the agent). In each familiarization trial, the agent reached around the transparent barrier and grasped object-A. In the test trial, the screens were removed, the objects' positions were switched, and the agent reached for either object-A (old-object event) or object-B (new-object event). The knowledge condition was identical except that before the familiarization trials the agent placed object-B in front of the opaque screen herself and thus knew of its presence there. Infants in the knowledge condition looked longer if shown the new-object as opposed to the old-object event, whereas infants in the ignorance condition looked equally at the two events. Thus, infants took into account the agent's knowledge when interpreting her actions during the familiarization trials. When the agent knew both objects were present, infants interpreted her repeated actions on object-A as demonstrating a preference for that object. In contrast, when the agent was ignorant about object-B's presence in the scene, infants realized that her actions on object-A could not be interpreted as signaling a preference (i.e., she might be reaching for object-A simply because she thought it was the only object present).

These findings were subsequently extended to 6-month-olds (Kim & Song 2015; Luo & Johnson 2009). For example, in an anticipatory-looking task modeled after that of Luo and Baillargeon (2007), Kim and Song (2015) found that infants in the knowledge condition anticipated that the agent would reach for object-A in the test trial, whereas infants in the ignorance condition showed no such anticipation. These results indicate that at least by 6 months of age, infants are non-egocentric: if an agent's representation of a scene is incomplete relative to their own, they use the agent's representation to predict and interpret the agent's actions.

By the second year of life, infants also use the agent's representation to guide their own actions in the scene. For example, Tomasello and Haberl (2003) found that when an agent requested one of three objects excitedly, 12- and 18-month-olds gave her the one she had not seen previously, suggesting that they kept track of which objects the agent had experienced during the testing session. Repacholi et al. (2008) also reported that after watching an agent angrily scold an experimenter for playing with an "irritating" toy, 18-month-olds were more likely to play with the toy if the agent did not look at them (e.g., if she read a magazine) than if she looked at them directly.

Finally, infants in the second year of life realize that just as they may see an object that an agent cannot see, an agent may see an object that they themselves cannot see (e.g., Chow et al. 2008; Moll & Tomasello 2004). For example, Moll and Tomasello (2004) found that when an agent looked behind an opaque barrier with expressions of excitement, 12- and 18-month-olds crawled or walked forward to peek around the barrier and see what the agent could see.

Keeping Track of What Events Agents Have Seen

Infants keep track of what events an agent has or has not witnessed in a scene, and they attribute appropriate epistemic states to the agent: they expect an agent who has witnessed an event to know about it, and they expect an agent who has not witnessed an event to be ignorant about it. For example, if an agent is present while an experimenter hides a preferred toy in one of two boxes, infants ages 6—18 months expect the agent to know the toy's location and to search the correct box, and they detect a violation if the agent searches the incorrect box instead (e.g., He & Baillargeon in prep.; Scott & Baillargeon 2009; Song & Baillargeon 2008; Surian et al. 2007). Conversely, if the agent is absent while the toy is hidden, infants expect the agent to be ignorant about the toy's location and to search either box at random (He & Baillargeon in prep; Scott & Baillargeon 2009). These results provide additional evidence that infants are non-egocentric and realize that an agent may know less about a scene than they do. In addition, these results make clear that infants expect agents to act in a manner consistent with both their motivational and epistemic states: an agent who wants her preferred toy and knows its location should search that location, in accordance with the consistency principle.

By the second year of life, infants use the knowledge available to an agent not only to interpret but also to predict the agent's actions (e.g., Meristo et al. 2012; Surian & Geraci 2012). In one anticipatory-looking task, for example, 17-month-olds watched events in which a triangle chased a circle, which finally hid in one of two boxes (Surian & Geraci 2012). When the triangle witnessed this hiding event, infants anticipated that it would approach the correct box to find the circle. Finally, infants' understanding of an agent's epistemic states also guides their own actions toward the agent. Thus, infants age 12 months and older spontaneously pointed to inform an agent about the current location of an object if she was absent when it was moved to a new location (Liszkowski et al. 2006) or if she was looking away when it fell to the floor (Liszkowski et al. 2008).

Evaluating Irrational Agents: The Case of Epistemic Unreliability

We saw earlier that when an agent acts irrationally (e.g., performs an unnecessary detour en route to a target), infants typically hold no expectation about the agent's subsequent actions. In some cases, infants may simply conclude that they lack sufficient information to understand the agent's actions. In other cases, however, infants may *evaluate* the agent as irrational and withhold future expectations, both in the original context in which the irrational action occurred as well as in new contexts; for infants as for adults, it is difficult to predict the actions of irrational agents or to trust new information they impart. Evidence for this second possibility comes from tasks on epistemic unreliability, which contrast reliable agents who act in accordance with their epistemic states and unreliable agents who do not.

In a series of *unreliable-looker* tasks, Poulin-Dubois and her colleagues tested whether 14—16-month-olds who saw an agent act in a manner inconsistent with her epistemic states in a first context would then hold no expectation about her behavior in a second context. In the first context, the agent expressed excitement ("Wow!") when looking inside a bucket that either contained a toy (reliable-looker condition) or was empty (unreliable-looker condition). The second context was adapted from prior tasks and varied across experiments, but in each case infants held expectations for the actions of the reliable but not the unreliable looker. Thus, infants were more likely to peek around a barrier after watching the reliable looker express excitement as she looked behind the barrier (Chow et al. 2008); they were more likely to detect a violation if the reliable looker failed to use her knowledge of an object's location when searching for it (Poulin-Dubois & Chow 2009); and they were more likely to activate a light-box with their foreheads after watching the reliable looker perform this novel inefficient action (Poulin-Dubois et al. 2011).

In an *unreliable-user* task, Zmyj et al. (2010) first showed 14-month-olds events in which an agent used everyday objects in either the typical manner (reliable-user condition; e.g., putting sunglasses on his nose and using a toothbrush to brush his teeth) or an atypical manner (unreliable-user condition; e.g., putting sunglasses on his foot and using a toothbrush to brush his hand). Next, the agent activated a light-box with his forehead, and infants in the reliable-user condition were more likely to imitate this novel inefficient action than were infants in the unreliable-user condition.

Finally, *unreliable-labeler* tasks take advantage of the fact that infants in the second year of life already know labels for many familiar objects (e.g., Begus & Southgate 2012; Brooker & Poulin-Dubois 2013; Koenig & Woodward 2010; Krogh-Jespersen & Echols 2012). In one task, for example, 18-month-olds first watched an agent label familiar objects either correctly (reliable-labeler condition) or incorrectly (unreliable-labeler condition). Infants were more likely to learn a novel label and to imitate a novel inefficient action taught by the reliable labeler as opposed to the unreliable labeler (Brooker & Poulin-Dubois 2013). Similarly, 16-month-olds were more likely to point to novel objects—as though requesting information about these objects (Kovács et al. 2014b)—if faced with a reliable as opposed to an unreliable labeler (Begus & Southgate 2012).

The preceding results suggest two broad conclusions. First, infants evaluate an agent who acts in a manner inconsistent with her epistemic states as irrational: they are less likely to seek information from her, to learn novel words and actions from her, or to detect a violation when she acts irrationally in a new context. This evaluation appears to be psychological rather than sociomoral in nature: 18-month-olds were equally likely to help a reliable or an unreliable labeler by bringing closer an object out of reach (Brooker & Poulin-Dubois 2013). Second, the preceding results extend our understanding of the consistency principle. Until now, our discussion of consistency violations has focused on situations where an agent with a demonstrated goal or preference suddenly deviated from it, for no apparent reason. What the research on epistemic unreliability makes clear is that in assessing consistency, infants bring to bear what they have learned from their social environments about how agents typically react to situations, use or label objects, and so on. Thus, an agent who emotes positively over an empty bucket, puts sunglasses on her foot, or labels a ball as a shoe is an agent who violates the consistency principle, given shared societal norms and conventions (for an interesting exception showing infants' sensitivity to humor cues, see Hoicka & Wang 2011).

ATTRIBUTING COUNTERFACTUAL STATES

The evidence reviewed in the preceding section indicates that beginning in the first year of life, infants recognize that agents may at times be ignorant about some aspect of a scene. But what happens when agents are not merely ignorant but hold false beliefs about a scene? Are infants able to reason about counterfactual states such as false beliefs?

For many years, it was widely assumed that the ability to attribute false beliefs did not emerge until about 4 years of age (e.g., Gopnik & Astington 1988; Wellman et al. 2001; Wimmer & Perner 1983). The evidence for this conclusion came primarily from *elicited-prediction* tasks in which children were asked to predict the behavior of an agent who held a false belief about a scene. In a classic task (Baron-Cohen et al. 1985), children listened to a story enacted with props: Sally hid a marble in a basket and then left; in her absence, Anne moved the marble to a nearby box; Sally then returned, and children were asked where she would look for her marble. Most 4-year-olds answered correctly and pointed to the basket (where Sally falsely believed the marble was); in contrast, most 3-year-olds pointed to the box (where the marble actually was), suggesting that they did not yet understand that Sally would hold a false belief about the marble's location.

Over the past decade, the conclusion that false-belief understanding does not emerge until the preschool years has been called into question by steadily accumulating evidence that children in the third, second, and even first year of life demonstrate such understanding when tested with other types of false-belief tasks (e.g., Baillargeon et al. 2010, 2015). Positive results have now been obtained with infants in *spontaneous-response* and *elicited-intervention* tasks. In both types of tasks, infants watch a scene in which an agent comes to hold a false belief. In spontaneous-response tasks, infants are asked no test question; instead, their spontaneous responses to the unfolding scene are measured. In elicited-intervention tasks, infants are asked a test question that prompts them to perform some action for the mistaken agent.

Spontaneous-Response False-Belief Tasks

The first spontaneous-response task with infants used the violation-of-expectation method and examined whether 15-month-olds would expect an agent to act in accordance with her false belief about a toy's location (Onishi & Baillargeon 2005). Infants first received familiarization trials in which an agent hid a toy in a green as opposed to a yellow box. Next, infants received one of four different belief-induction trials that resulted in the agent believing, truly or falsely, that the toy was in the green or the yellow box: in the knowledge-green condition, the agent watched as the yellow box moved a short distance and then returned to its original position; in the false-belief-green condition, the agent was absent when the toy moved from the green box into the yellow box; in the knowledge-yellow condition, the agent saw the toy move into the yellow box; finally, in the false-belief-yellow condition, the agent watched as the toy moved into the yellow box, but was absent when it returned to the green box. In the test trial, the agent reached into either the green or the yellow box and then paused. In each condition, infants expected the agent to act on the information available to her, whether it was true or false: thus, infants in the knowledge-green and false-belief-green conditions expected the agent to reach into the green box, whereas infants in the knowledge-yellow and false-belief-yellow conditions expected her to reach into the yellow box. In each case, infants detected a consistency violation when the agent searched the other box.

The results of Onishi and Baillargeon (2005) have been confirmed and extended in many other spontaneous-response tasks. First, infants' reasoning about false beliefs about location (like their reasoning about other mental states) is highly context-sensitive. For example, infants expect an agent *not* to hold a false belief about an object's location (a) if she wears a see-through as opposed to an opaque blindfold while the object is moved (Senju et al. 2011), (b) if she can see part of the object in its new location when she returns (Surian et al. 2007), (c) if she is given relevant information (e.g., "The ball is in the cup!"), as opposed to irrelevant information (e.g., "I like the cup!"), about the object's new location (Song et al. 2008), and (d) if the object rolls down a beam to its new location because the agent tipped the beam with her hand while looking away (Träuble et al. 2010).

Second, infants understand not only false beliefs about the location of an object, but also false beliefs about the presence, properties, and identity of an object (e.g., Scott & Baillargeon 2009; Scott et al. 2010; Song & Baillargeon 2008; Southgate & Vernetti 2014). In a task on identity (Scott & Baillargeon 2009), for example, 18-month-olds first received familiarization trials in which an agent faced a 1-piece penguin that did not come apart and a disassembled 2-piece penguin. In each trial, the agent hid a small key in the bottom piece of the 2-piece penguin and then assembled it; once assembled, the 2-piece penguin was identical to the 1-piece penguin. In the test trials, while the agent was absent, an experimenter assembled the 2-piece penguin, placed it under a transparent cover, and then placed the 1-piece penguin under an opaque cover. The agent then returned with her key and reached for either the transparent or the opaque cover and then paused. Infants expected the agent to reach for the opaque cover and looked longer when she reached for the transparent cover instead (this looking pattern reversed if the agent witnessed the experimenter's actions). These results indicated that infants expected the agent (a) to mistake the penguin visible under the transparent cover for the 1-piece penguin (because the 2-piece penguin had always been disassembled at the start of the familiarization trials) and hence (b) to falsely conclude that the disassembled 2-piece penguin was hidden under the opaque cover (because both penguins were always present in the familiarization trials). Infants thus attributed to the agent not just one but two interlocking false beliefs.

Third, infants take into account an agent's false belief(s) not only to interpret the agent's actions (e.g., to understand why the agent approaches the wrong location to find a desired object), but also to predict the agent's actions and to guide their own actions toward the agent. In anticipatory-looking tasks, 17- to 25-month-olds spontaneously anticipated that an agent who believed an object was in location-A (when it was in fact in location-B or had been removed from the scene) would search location-A for the object (e.g., Meristo et al. 2012; Senju et al. 2011; Southgate et al. 2007; Surian & Geraci 2012). In anticipatory-pointing tasks, 18-month-olds spontaneously pointed to inform a mistaken agent that an object had been moved to a new location (Knudsen & Liszkowski 2012a) or that an aversive object had been placed at the location she falsely believed held her desired object (Knudsen & Liszkowski 2012b).

Fourth, the evidence that infants represent others' false beliefs now extends to the first year of life (e.g., Kovács et al. 2010; Luo 2011a; Southgate & Vernetti 2014). In a looking-time task, for example, 7-month-olds first received familiarization trials in which a Smurf agent placed a self-propelled ball in front of an occluder; the ball then moved behind the occluder, which was lowered to reveal the ball. In the test trials, infants saw a knowledge and a false-belief event. In the knowledge event, the agent again introduced the ball and watched as it first moved behind the occluder and then exited the scene; finally, the occluder was lowered to reveal no ball. The false-belief event was identical except that the agent left after the ball moved behind the occluder and returned only after the ball had exited the scene. Infants looked longer at the false-belief than at the knowledge event, and this effect was eliminated if the occluder was not lowered at the end of the events. These and other results indicated that when watching the false-belief event, infants expected the agent (a) to falsely believe the ball was still present behind the occluder and hence (b) to be surprised by the ball's disappearance and perhaps also to generate an explanation for it (as do 6-month-olds when a self-propelled object slips out of view to a new location; Luo et al. 2009). Evidence that young infants can not only interpret but also predict the actions of mistaken agents comes from an EEG experiment that measured 6-month-olds' sensorimotor-cortex activation as they watched false-belief events (Southgate & Vernetti 2014). Compared to a baseline period, infants showed motor activation when an agent falsely believed a box contained a ball, but they showed no motor activation when the agent falsely believed the box contained no ball. Infants thus anticipated that the agent would search for the ball when she falsely believed it was present, but not when she falsely believed it was absent.

Fifth, evidence of false-belief understanding has also been obtained with toddlers in the third year of life (ages 2—3 years) using various spontaneous-response tasks (e.g., He et al. 2011, 2012; Scott et al. 2012). Importantly, some of these tasks have been highly verbal, with linguistic demands comparable to those of elicited-prediction tasks (He et al. 2012; Scott et al. 2012). In one violation-of-expectation task, for example, 2.5-year-olds watched a typical Sally-Anne scene along with an adult "subject" who was then asked where Sally would look for her toy when she returned (Scott et al. 2012). Children looked longer when the "subject" responded incorrectly and pointed to the toy's current as opposed to original location. Similarly, in a preferential-looking task, 2.5-year-olds listened to a false-belief story, accompanied by a picture book, about a character named Emily and her apple (Scott et al. 2012). In the final double-page of the book, one picture showed Emily searching for her apple where she falsely believed it to be (original-location picture), and the other picture showed Emily searching for her apple in its current location (current-location picture). Upon hearing the final line of the story, which stated that Emily was looking for her apple, children looked preferentially at the original-location picture, suggesting that they represented Emily's false belief and understood how it would guide her actions. These results make clear that the reason why young children fail at elicited-prediction tasks but succeed at spontaneous-response tasks is not simply that the former are highly verbal whereas the latter are not; young children succeed even at highly verbal spontaneous-response false-belief tasks.

Finally, positive results have been obtained using non-verbal and highly verbal spontaneous-response false-belief tasks not only with young Western children, but also with 22- to 40-month-old children from three traditional non-Western societies: a Salar community in northwest China, a predominantly Shuar community in southeastern Ecuador, and a Yasawan community in northwest Fiji (Barrett et al. 2013).

Elicited-Intervention False-Belief Tasks

In elicited-intervention false-belief tasks, infants are asked a test question, but this question does not require them to predict the behavior of a mistaken agent: instead, they are prompted to perform an action such as retrieving or selecting an object for the agent; for infants to succeed, their actions must be guided by an understanding of the agent's false belief. In the helping task of Buttelmann et al. (2009), an experimenter first showed 18-month-olds how to lock and unlock two lidded boxes; the boxes were left unlocked. Next, a male agent entered the room, hid a toy in one of the boxes, and then left. While he was gone, the experimenter moved the toy to the other box and locked both boxes. When the agent returned, he tried to open the box where he had hidden his toy, without success, and then sat centered behind the boxes. When prompted to help the agent ("Go on, help him!"), most infants approached the box the agent had not acted on, suggesting that they understood he wanted his toy and falsely believed it was still in its original location (when the agent witnessed the toy's transfer, infants inferred that he wanted to open the empty box, and they approached that box instead).

In the referential-communication task of Southgate et al. (2010), 17-month-olds watched as an agent hid two distinct objects in two lidded boxes and then left; in her absence, an experimenter switched the objects. When the agent returned, she pointed to one of the boxes and said it contained a “sefo”. The agent then opened the two boxes and asked infants, “Can you get the sefo for me?” Most infants approached the box the agent had not pointed to, suggesting that they understood the agent held a false belief about which object was in which box and intended to label the other object as the sefo. Similar results were obtained when the agent simply pointed to one of the boxes, said she wanted to play with the object in it, and asked the infants, “Can you get it for me?”

In addition to false beliefs about location, elicited-intervention tasks have been used to examine infants’ understanding of false beliefs about contents and identity (Buttelmann et al. 2014, 2015). In an unexpected-contents task (Buttelmann et al. 2014), 18-month-olds and an agent first encountered three “block boxes” that each contained a block. Next, in the agent’s absence, infants learned that a fourth block box actually contained a spoon. When the agent returned and reached vainly for the fourth block box, infants were shown a block and a spoon and asked to give one to the agent. Similarly, in a deceptive-identity task (Buttelmann et al. 2015), 18-month-olds and an agent first encountered an object that appeared to be a toy duck. Next, in the agent’s absence, infants learned that the object was actually a brush. When the agent returned and reached vainly for the object, infants were shown a (non-deceptive) toy duck and a brush and asked to give one to the agent. In each task, infants correctly selected the object that matched the agent’s false belief (i.e., the block and the duck, respectively); this pattern reversed if the agent remained present during the relevant demonstrations.

HOW SHOULD EARLY PSYCHOLOGICAL REASONING BE CHARACTERIZED?

We have argued, based on the findings presented in this review, that early psychological reasoning is mentalistic: infants attribute to agents motivational, epistemic, and counterfactual mental states, and they use these mental states—together with the principle of rationality—to predict, interpret, and evaluate agents' actions and to guide their own actions toward the agents. Several alternative interpretations have been offered for these findings.

Alternative Interpretations

According to some views, infants are not yet capable of genuine psychological reasoning. In the *low-level-process* view, infants represent events in psychological-reasoning experiments "as colours, shapes, and movements, rather than as actions on objects by agents" (Heyes, 2014, p. 648), and their responses are driven by perceptual novelty and other low-level domain-general processes. In the *behavioral-rule* view, infants do perceive agents acting on objects, but their expectations about agents are statistical rather than causal. In everyday life, infants gather information, in the form of statistical regularities or behavioral rules, about how agents typically behave in specific situations (e.g., an agent will search for an object where it was last seen); infants then apply these rules to interpret or predict agents' actions (e.g., Perner 2010; Ruffman 2014). Given the wealth of findings available today, these views seem unlikely. Infants' psychological reasoning is highly context-sensitive, and a myriad of low-level processes or behavioral rules would be needed to explain all these findings. It seems more plausible to grant infants an abstract capacity for making sense of agents' actions (for further discussion, see Baillargeon et al. 2015; Carruthers 2013; Jacob in press; Scott 2014).

According to the *teleological* view, young infants do engage in psychological reasoning and abide by a principle of rationality, but their reasoning is at first non-mentalistic and reality-based. More specifically, (a) infants deal exclusively with physical variables such as situational constraints and end-states (infants do not attribute goals to agent, but simply track the outcomes they achieve), and (b) infants are egocentric and cannot entertain a representation of reality that is different from their own (Gergely et al. 1995; Gergely & Csibra 2003). The recent evidence that even young infants appreciate that an agent may be ignorant or mistaken about some aspect of a scene is inconsistent with the teleological view, or at least suggests that psychological reasoning is already mentalistic by the first half birthday.

According to the *minimalist* view, infants' psychological-reasoning system is mentalistic from the start, but the range of mental states it can handle is sharply limited: in particular, it cannot represent false beliefs and other counterfactual states, although it can track belief-like states or "registrations" that are sufficient for success at many spontaneous-response and elicited-intervention tasks (e.g., Apperly & Butterfill 2009; Butterfill & Apperly 2013). Upon encountering an object, an agent registers its location and properties; by tracking this registration (even if its contents become outdated), infants can predict the agent's actions. For example, if an agent hides an object in one location and in her absence the object is moved to another location, infants can anticipate that the agent, upon returning to the scene, will search for the object where she last registered it. According to the minimalist view, infants' psychological-reasoning system presents a number of "signature" limits, which include (a) an inability to represent false beliefs about identity (these require taking into account not only *what* objects are registered but also *how* they are registered), and (b) an inability to reason about a complex, interlocking set of mental states that interact causally (e.g., Apperly & Butterfill 2009; Butterfill & Apperly 2013; Low et al. 2014; Low & Watts 2013). However, there is reason to doubt both of these limits: infants have now been found to attribute false beliefs about identity in several tasks, and success at these tasks typically requires reasoning about an interlocking, causally coherent set of motivational, epistemic, and counterfactual states (e.g., Buttelmann et al. 2015; Scott & Baillargeon 2009; Scott et al. 2015a; Song & Baillargeon 2008). For example, recent experiments examined whether 17-month-olds could reason about the actions of a deceptive agent who sought to implant in another agent a false belief about the identity of an object (Scott et al. 2015a). In each experiment, a thief attempted to secretly steal a desirable rattling toy during its owner's absence by substituting a less desirable silent toy. Infants realized that this substitution could be effective only if the silent toy was visually identical to the rattling toy and the owner did not routinely shake her toy when she returned; when these conditions were met, infants expected the owner to be deceived and to mistake the silent toy for the rattling toy she had left behind. These results suggest that infants in the second year of life can reason not only about the actions of agents who hold false beliefs about identity, but also about the actions of agents who seek to *implant* such false beliefs, providing strong support for the mentalistic view that an abstract capacity to represent and reason about false beliefs is already present in infancy.

Implicit and Explicit Psychological Reasoning

What does implicit mean? Infants' psychological reasoning is often characterized as implicit, but different investigators mean different things by this term. One meaning (akin to *sham*) refers to processes that mimic more advanced, explicit processes but do not, in fact, involve the same concepts (e.g., if infants represented that "an object and another object" were in a box, they would have only an implicit understanding of the concept "two", as this concept would not figure in any way in their reasoning). Another meaning of the term implicit (akin to *unconscious*) refers to reasoning that occurs without explicit awareness of either the processes at work or the contents they generate. Yet another meaning of the term implicit (akin to *intuitive*) refers to reasoning that occurs without conscious awareness of the processes involved, but can be accompanied by awareness of the contents generated.

Given the evidence reviewed in this article, the *intuitive* meaning of the term implicit comes closest to describing infants' psychological reasoning. As Vierkant (2012) argued, it is unlikely that infants in false-belief tasks who produce actions such as retrieving, selecting, and pointing to objects are unaware of these actions: "There might well be some false-belief understanding that cannot yet be deliberated about by a child, but which can nevertheless inform the fully consciously controlled actions of that child. . .The child makes a conscious choice, and this choice turns out to be an appropriate one, because it was influenced by the child's false-belief understanding. . .The behavior is not controlled by an unconscious zombie system. . . but by a conscious agent" (Vierkant 2012, p. 154).

Explicit reasoning does not supplant intuitive reasoning. Like infants, older children and adults routinely engage in intuitive reasoning about others' actions (e.g., Brown-Schmidt et al. 2008; German & Cohen 2012; Kovács et al. 2010; Senju et al. 2009); unlike infants, however, older children and adults are also capable of explicit psychological reasoning. First, they can consciously deliberate about others' actions and verbalize their understanding of these actions (e.g., they can explain that Sally will go to the basket because she thinks her marble is still there; Amsterlaw & Wellman 2006; Bartsch & Wellman 1989). Second, they develop a folk theory of psychology (just as they develop folk theories of astronomy and biology; e.g., Carey 1985; Vosniadou & Brewer 1992), which enables them to think and talk about theoretical concepts such as false beliefs (e.g., Gopnik & Wellman 1994; Leslie 2000).

There is currently a heated debate about how explicit psychological reasoning develops, how it relates to implicit psychological reasoning (in children and in adults), and whether its emergence is what makes possible children's success at elicited-prediction false-belief tasks (e.g., when a 4-year-old points to the correct location in such a task, this action is certainly consciously controlled, but does it necessarily reflect an explicit reasoning process?). These issues represent the new frontier in the research on early psychological reasoning, and findings from behavioral and neuroscientific methods are producing new insights (e.g., Hyde et al. in press; Kovács et al. 2014a). One other approach is also yielding thought-provoking results: over the past few years, researchers have begun to conduct longitudinal studies exploring the continuity of psychological reasoning from infancy to childhood (e.g., Aschersleben et al. 2008; Thoermer et al. 2012; Wellman et al. 2008; Yamaguchi et al. 2009). Although results have been somewhat variable due to small samples, several studies have reported significant correlations involving false-belief understanding: in a recent study, for example, performance in an anticipatory-looking task at 18 months predicted performance in various elicited-prediction tasks at 50 months (Sodian et al. 2015). These results not only point to substantial continuity in early psychological reasoning, but also raise important questions about individual differences and the factors responsible for them.

Finally, in light of the preceding discussion, it may be clearer why in this review we chose to refer to infants' ability to infer others' mental states as "psychological reasoning" rather than as "theory of mind", as is often the case. We prefer the term psychological reasoning for two reasons (see also Schaafsma et al. 2015). First, this term underscores the deep similarities between infants' psychological reasoning and their reasoning in other core domains of causal reasoning, such as physical and sociomoral reasoning (e.g., Baillargeon et al. 2013, 2015). Second, the term theory of mind sometimes fosters the assumption that the acquisition of a folk theory of psychology is the primary endpoint of development in this domain and allows an explicit form of reasoning to supplant a more intuitive form of reasoning. As we have just seen, intuitive psychological reasoning persists throughout life, and its relation to explicit psychological reasoning is far from being completely understood.

CONCLUSION

The extensive evidence reviewed in this article indicates that from a very early age, psychological reasoning is mentalistic in nature. Upon observing an agent act in a scene, infants attempt to infer the agent's motivational, epistemic, and counterfactual states; infants then use these mental states, together with the principle of rationality, to predict and interpret the agent's subsequent actions and to guide their own actions toward the agent. Much remains to be discovered about how infants' ability to infer and reason about others' mental states improves with age, about the maturation of the brain networks that underlie this ability, and about the various factors that contribute to individual differences in neurotypical and other populations. Nevertheless, it seems clear that this core domain of causal reasoning depends on a content-rich, adaptive, neurocomputational system that begins to operate early in life (Cosmides & Tooby 2013).

ACKNOWLEDGMENTS

We wish to thank Shelley Taylor and Lisa Dean for their suggestions, support, and patience, as well as Andrei Cimpian, Melody Buyukozer Dawkins, Cynthia Fisher, Gerald DeJong, Francesco Margoni, and Francisca Ting for helpful comments.

DISCLOSURE STATEMENT

The authors are not aware of any affiliations, memberships, funding, or financial holdings that might be perceived as affecting the objectivity of this review.

LITERATURE CITED

Amsterlaw J, Wellman HM. 2006. Theories of mind in transition: A microgenetic study of the development of false belief understanding. *J. Cogn. Dev.* 7:139-72

Apperly IA, Butterfill SA. 2009. Do humans have two systems to track beliefs and belief-like states? *Psychol. Rev.* 116:953-70

Arterberry ME, Bornstein MH. 2002. Infant perceptual and conceptual categorization: the roles of static and dynamic stimulus attributes. *Cognition* 86:1-24

Aschersleben G, Hofer T, Jovanovic B. 2008. The link between infant attention to goal-directed action and later theory of mind abilities. *Developmental Sci.* 11:862-68

Baillargeon R, He Z, Setoh P, Scott, RM, Sloane S, Yang DYJ. 2013. False-belief understanding and why it matters: The social-acting hypothesis. In *Navigating the social world: What infants, children, and other species can teach us* ed. MR Banaji, SA Gelman, pp. 88-95. New York, NY: Oxford University Press

Baillargeon R, Scott RM, He Z. 2010. False-belief understanding in infants. *Trends Cogn. Sci.* 14:110-18

Baillargeon R, Scott RM, He Z, Sloane S, Setoh P, Jin K, Wu D, Bian L. 2015. Psychological and sociomoral reasoning in infancy. In *APA Handbook of Personality and Social Psychology: Vol.1. Attitudes and Social Cognition* ed. M Mikulincer, PR Shaver, Assoc. ed. E Borgida, JA Bargh, pp. 79-150. Washington, DC: American Psychological Association

Baillargeon R, Setoh P, Sloane S, Jin K, Bian L. 2014. Infant social cognition: Psychological and sociomoral reasoning. In *The cognitive neurosciences* ed. MS Gazzaniga, GR Mangun, 5th ed:7-14. Cambridge, MA: MIT Press

Baillargeon R, Wu D, Yuan S, Li J, Luo Y. 2009. Young infants' expectations about self-propelled objects. In *The origins of object knowledge* ed. B Hood, L Santos, pp. 285-352. Oxford, England: Oxford University Press

Barna J, Legerstee M. 2005. Nine- and twelve-month-old infants relate emotions to people's actions. *Cognition Emotion* 19:53-67

Baron-Cohen S. 1995. *Mind blindness: An essay on autism and theory of mind*. Cambridge, MA: MIT Press/Bradford Books

Baron-Cohen S, Leslie AM, Frith U. 1985. Does the autistic child have a "theory of mind"? *Cognition* 21:37-46

Barrett HC, Broesch T, Scott RM, He Z, Baillargeon R et al. 2013. Early false-belief understanding in traditional non-Western societies. *P. Roy. Soc. B-Biol Sci* 280:20122654

Bartsch K, Wellman H. 1989. Young children's attribution of action to beliefs and desires. *Child Dev.* 60:946-64

Begus K, Southgate V. 2012. Infant pointing serves an interrogative function. *Developmental Sci.* 15:611-17

Beier JS, Carey S. 2014. Contingency is not enough: Social context guides third-party attributions of intentional agency. *Developmental Psychol*. *50*:889-902.

Bíró S. 2013. The role of the efficiency of novel actions in infants' goal anticipation. *J Exp. Child Psychol.* 116:415-27

Bíró S, Csibra G, Gergely G. 2007. The role of behavioral cues in understanding goal-directed action in infancy. *Prog. Brain Res.* 164:303-22

Bíró S, Verschoor S, Coalter E, Leslie AM. 2014. Outcome producing potential influences twelve-month-olds' interpretation of a novel action as goal-directed. *Infant Beh. Dev*. 37: 729-38

Bíró S, Verschoor S, Coenen L. 2011. Evidence for a unitary goal concept in 12-month-old infants. *Developmental Sci.* 14:1255-60

Bloom P. 2013. *Just Babies: The origins of good and evil.* New York: Crown.

Brandone AC, Horwitz SR, Aslin RN, Wellman HM. 2014. Infants' goal anticipation during failed and successful reaching actions. *Developmental Sci.* 17: 23-34

Brandone AC, Wellman HM. 2009. You can't always get what you want: Infants understand failed goal-directed actions. *Psychol. Sci*. 20:85-91

Brooker I, Poulin-Dubois D. 2013. Is a bird an apple? The effect of speaker labeling accuracy on infants' word learning, imitation, and helping behaviors. *Infancy* 18:E46-E68

Brown-Schmidt S, Gunlogson C, Tanenhaus MK. 2008. Addressees distinguish shared from private information when interpreting questions during interactive conversation. *Cognition* 107:1122-34

Brugger A, Lariviere LA, Mumme DL, Bushnell EW. 2007. Doing the right thing: Infants' selection of actions to imitate from observed event sequences. *Child Dev*. 78:806-24

Buresh JS, Woodward AL. 2007. Infants track action goals within and across agents. *Cognition* 104:287-314

Butterfill S, Apperly IA. 2013. How to construct a minimal theory of mind. *Mind Lan.* 28:606-37

Buttelmann D, Carpenter M, Tomasello M. 2009. Eighteen-month-old infants show false belief understanding in an active helping paradigm. *Cognition* 112:337-42

Buttelmann D, Over H, Carpenter M, Tomasello M. 2014. Eighteen-month-olds understand false beliefs in an unexpected-contents task. *J. Exp. Child Psychol.* 119:120-26

Buttelmann F, Suhrke J, Buttelmann D. 2015. What you get is what you believe: Eighteen-month-olds demonstrate belief understanding in an unexpected-identity task. *J Exp. Child Psychol.* 131:94-103

Cannon E. Woodward AL. 2012. Infants generate goal-based action predictions. *Developmental Sci*. 15:292-98

Carey S. 1985. *Conceptual change in childhood*. Cambridge, MA: MIT Press

Carpenter M, Call J, Tomasello M. 2005. Twelve- and 18-month-olds copy actions in terms of goals. *Developmental Sci.* 8:F13-F20

Carpenter M, Nagell K, Tomasello M. 1998. Social cognition, joint attention, and communicative competence from 9 to 15 months of age. *Monogr. Soc. Res. Child.* 63:1-143

Carruthers P. 2013. Mindreading in infancy. *Mind Lang.* 28:141-72

Chow V, Poulin-Dubois D, Lewis J. 2008. To see or not to see: Infants prefer to follow the gaze of a reliable looker. *Developmental Sci.* 11:761-70

Cosmides L, Tooby J. 2013. Evolutionary psychology: New perspectives on cognition and motivation. *Annu. Rev. Psychol.* 64:201-29

Csibra G. 2008. Goal attribution to inanimate agents by 6.5-month-old infants. *Cognition* 107: 705-17

Csibra G, Bíró S, Koós O, Gergely G. 2003. One-year-old infants use teleological representations of actions productively. *Cognitive Sci.* 27:111-33

Csibra G, Gergely G. 2009. Natural pedagogy. *Trends Cogn. Sci.* 13:148-53

Deligianni F, Senju A, Gergely G, Csibra G. 2011. Automated gaze-contingent objects elicit orientation following in 8-months-old infants. *Developmental Psychol.* 47:1499-1503

Dennett DC. 1987. *The intentional stance.* Cambridge, MA: MIT Press

Egyed K, Király I, Gergely G. 2013. Communicating shared knowledge in infancy. *Psychol. Sci*. 24: 1348-53

Esseily R, Rat-Fischer L, O'Regan K, Fagard J. 2013. Understanding the experimenter's intention improves 16-month-olds' observational learning of the use of a novel tool. *Cognitive Dev*. 28: 1-9

Gergely G, Bekkering H, Király I. 2002. Rational imitation in preverbal infants. *Nature* 415:755

Gergely G, Csibra G. 2003. Teleological reasoning in infancy: The naıve theory of rational action. *Trends Cogn. Sci.* 7:287-92

Gergely G, Nádasdy Z, Csibra G, Bíró S. 1995. Taking the intentional stance at 12 months of age. *Cognition* 56:165-93

German TC, Cohen AS. 2012. A cue-based approach to 'theory of mind': Re-examining the notion of automaticity. *Brit. J. Dev. Psychol.* 30:45-58

Gerson SA, Woodward AL. 2012. A claw is like my hand: Comparison supports goal analysis in infants. *Cognition* 122:181-92

Gerson SA, Woodward AL. 2013. The goal trumps the means: highlighting goals is more beneficial than highlighting means in means-end training. *Infancy* 18:289-302

Gerson SA, Woodward AL. 2014. Learning from their own actions: The unique effect of producing actions on infants' action understanding. *Child Dev*. 85:264-77

Gopnik A, Astington JW. 1988. Children's understanding of representational change and its relation to the understanding of false belief and the appearance-reality distinction. *Child Dev.* 59:26-37

Gopnik A, & Wellman HM. 1994. The theory theory. In *Mapping the mind: Domain specificity in cognition and culture* eds. LA Hirschfeld & SA Gelman, pp. 257–93. New York, NY: Cambridge University Press

Gweon H, Tenenbaum JB, Schulz LE. 2010. Infants consider both the sample and the sampling process in inductive generalization. *P. Natl. Acad. Sci. USA* 107: 9066-71

Hamlin JK. 2013. Moral judgment and action in preverbal infants and toddlers: Evidence for an innate moral core. *Current Directions Psychol. Sci*. 22:186-93

Hamlin JK, Wynn K. 2011. Young infants prefer prosocial to antisocial others. *Cognitive Dev.* 26:30-39

Hamlin JK, Wynn K, Bloom P. 2007. Social evaluation by preverbal infants. *Nature* 450:557-59

Hamlin JK, Wynn K, Bloom P. 2010. Three-month-olds show a negativity bias in their social evaluations. *Developmental Sci*. 13:923-29

He Z, Bolz M, Baillargeon R. 2011. False-belief understanding in 2.5-year-olds: Evidence from violation-of-expectation change-of-location and unexpected-contents tasks. *Developmental Sci.* 14:292-305

He Z, Bolz M, Baillargeon R. 2012. 2.5-year-olds succeed at a verbal anticipatory-looking false-belief task. *Brit. J. Dev. Psychol.* 30:14-29

Henderson AME, Woodward AL. 2012. Nine-month-old infants generalize object labels, but not object preferences across individuals. *Developmental Sci.* 15:641-52

Henrichs I, Elsner C, Elsner B, Wilkinson N, Gredebäck G. 2014. Goal certainty modulates infants' goal-directed gaze shifts. *Developmental Psychol.* 50:100-7

Hepach R, Westermann G. 2013. Infants' sensitivity to the congruence of others' emotions and actions. *J Exp. Child Psychol*. 115: 16-29

Hernik M, Southgate V. 2012. Nine-month-old infants do not need to know what the agent prefers in order to reason about its goals: On the role of preference and persistence in infants' goal-attribution. *Developmental Sci.* 15:714-22

Heyes C. 2014. False belief in infancy: a fresh look. *Developmental Sci.* 17:647-59

Hoicka E, Wang S. 2011. Fifteen-month-old infants match vocal cues to intentional actions. *J Cogn. Dev.* 12:299-314

Hunnius S, Bekkering H. 2010. The early development of object knowledge: A study of infants' visual anticipations during action observation. *Developmental Psychol*. 46:446-54

Hyde DC, Aparicio Betancourt M, Simon CE. in press. Human temporal-parietal junction automatically tracks other's beliefs: An fNIRS study. *Human Brain Mapping*.

Jacob P. in press. A puzzle about belief-ascription. In *Mind and Society: Cognitive Science Meets the Social Sciences* ed. B. Kaldis. Berlin, Germany: Synthese Library, Springer

Johnson SC. 2005. Reasoning about intentionality in preverbal infants. In *The innate mind: Vol. 1. Structure and contents* ed. P Carruthers, S Laurence, S Stich, 254-71. Oxford, England: Oxford University Press

Johnson SC, Bolz M, Carter E, Mandsanger J, Teichner A, Zettler P. 2008. Calculating the attentional orientation of an unfamiliar agent in infancy. *Cognitive Dev*. 23:24-37

Johnson SC, Booth A, O'Hearn K. 2001. Inferring the goals of a nonhuman agent. *Cognitive Dev*. 16:637-56

Johnson SC, Dweck CS, Chen FS, Stern HL, Ok S-J, Barth ME. 2010. At the intersection of social and cognitive development: Internal working models of attachment in infancy. *Cognitive Sci.* 34:807-25

Johnson SC, OK S, Luo Y. 2007a. The attribution of attention: Nine-month-olds' interpretation of gaze as goal-directed action. *Developmental Sci*. 10:530-37

Johnson SC, Shimizu YA. Ok S-J. 2007b. Actors and actions: The role of agent behavior in infants' attribution of goals. *Cognitive Dev*. 22:310-22.

Kamewari K, Kato M, Kanda T, Ishiguro H, Hiraki K. 2005. Six-and-a-half-month-old children positively attribute goals to human action and to humanoid-robot motion. *Cognitive Dev*. 20:303-20

Kanakogi Y, Itakura S. 2011. Developmental correspondence between action prediction and motor ability in early infancy. *Nat. Comms*. 2:341

Keil FC. 1995. The growth of causal understandings of natural kinds: Modes of construal and the emergence of biological thought. In *Causal Cognition* ed. A Premack, D Sperber, 234-67. Oxford: Oxford University Press

Kim E, Song H. 2015. Six-month-olds actively predict others' goal-directed actions. *Cognitive Dev.* 33:1-13

Király I, Csibra G, Gergely G. 2013. Beyond rational imitation: Learning arbitrary means actions from communicative demonstrations. *J Exp. Child Psychol.* 116:471-86

Király I, Jovanovic B, Prinz W, Aschersleben G, Gergely G. 2003. The early origins of goal attribution in infancy. *Conscious. Cogn.* 12:752-69

Knudsen B, Liszkowski U. 2012a. Eighteen- and 24-month-old infants correct others in anticipation of action mistakes. *Developmental Sci.* 15:113-22.

Knudsen B, Liszkowski U. 2012b. 18-month-olds predict specific action mistakes through attribution of false belief, not ignorance, and intervene accordingly. *Infancy* 17:672-91

Koenig MA, Woodward AL. 2010. Sensitivity of 24-month-olds to the prior inaccuracy of the source: Possible mechanisms. *Dev. Psychol.* 46:815-26

Kovács ÁM, Kuehn S, Gergely G, Csibra G, Brass M. 2014a. Are all beliefs equal? Implicit belief attributions recruiting core brain regions of theory of mind. PLoS ONE 9:e106558.

Kovács ÁM, Tauzin T, Téglás E, Gergely G, & Csibra G. 2014b. Pointing as epistemic request: 12−month−olds point to receive new information. *Infancy* 19:543-57

Kovács ÁM, Téglás E, Endress AD. 2010. The social sense: Susceptibility to others' beliefs in human infants and adults. *Science* 330:1830-34

Krogh-Jespersen S, Echols CH. 2012. The influence of speaker reliability on first versus second label learning. *Child Dev.* 83:581-90

Kuhlmeier V, Wynn K, Bloom P. 2003. Attribution of dispositional states by 12-month-olds. *Psychol. Sci*. 14:402-8

Kushnir T, Xu F, Wellman HM. 2010. Young children use statistical sampling to infer the preferences of other people. *Psychol. Sci.* 21:1134-40

Leslie AM. 1994. ToMM, ToBy, and agency: Core architecture and domain specificity. In *Mapping the mind: Domain specificity in cognition* ed. LA Hirschfeld, SA Gelman, 119-48. New York, NY: Cambridge University Press

Leslie AM. 2000. How to acquire a "representational theory of mind." In *Metarepresentations: A multidisciplinary perspective* ed. D Sperber, pp. 197-223. Oxford, England: Oxford University Press

Liszkowski U, Carpenter M, Striano T, Tomasello M. 2006. Twelve- and 18-month-olds point to provide information for others. *J Cogn. Dev.* 7:173-87

Liszkowski U, Carpenter M, Tomasello M. 2008. Twelve-month-olds communicate helpfully and appropriately for knowledgeable and ignorant partners. *Cognition* 108:732-39

LoBue V, Bloom Pickard M, Sherman K, Axford C, DeLoache JS. 2013. Young children's interest in live animals. *Brit. J. Dev. Psychol*. 31:57-69

Low J, Drummond W, Walmsley A, & Wang B. 2014. Representing how rabbits quack and competitors act: Limits on preschoolers' efficient ability to track perspectives. *Child Dev.* 85:1519-34

Low J, Watts J. 2013. Attributing false beliefs about object identity reveals a signature blind spot in humans' efficient mind-reading system. *Psychol. Sci.* 24:305-11

Luo Y. 2010. Do 8-month-old infants consider situational constraints when interpreting others' gaze as goal-directed action? *Infancy* 15:392-419

Luo Y. 2011a. Do 10-month-old infants understand others' false beliefs? *Cognition 121*:289-98

Luo Y. 2011b. Three-month-old infants attribute goals to a non-human agent. *Developmental Sci*. 14:453-60

Luo Y, Baillargeon R. 2005a. Can a self-propelled box have a goal? Psychological reasoning in 5-month-old infants. *Psychol. Sci.* 16:601-8

Luo Y, Baillargeon R. 2005b. When the ordinary seems unexpected: Evidence for incremental physical knowledge in young infants. *Cognition* 95:297-328

Luo Y, Baillargeon R. 2007. Do 12.5-month-old infants consider what objects others can see when interpreting their actions? *Cognition* 105:489-512

Luo Y, Beck W. 2010. Do you see what I see? Infants' reasoning about others' incomplete perceptions. *Developmental Sci.* 13:134-42

Luo Y, Johnson SC. 2009. Recognizing the role of perception in action at 6 months. *Developmental Sci.* 12:142-49

Luo Y, Kaufman L, Baillargeon R. 2009. Young infants' reasoning about events involving inert and self-propelled objects. *Cognitive Psychol.* 58:441-86

Martin A, Onishi KH, Vouloumanos A. 2012. Understanding the abstract role of speech in communication at 12 months. *Cognition* 123:50-60

Meltzoff AN. 1988. Infant imitation after a 1-week delay: Long-term memory for novel acts and multiple stimuli. *Developmental Psychol.* 24:470-76

Meltzoff AN. 1995. Understanding the intentions of others: Re-enactment of intended acts by 18-month-old children. *Developmental Psychol*. 31:838-50

Meristo M, Morgan G, Geraci A, Iozzi L, Hjelmquist E et al. 2012. Belief attribution in deaf and hearing infants. *Developmental Sci.* 15:633-40

Meristo M, Surian L. 2013. Do infants detect indirect reciprocity? *Cognition* 129:102-13

Moll H, Tomasello M. 2004. 12- and 18-month-old infants follow gaze to spaces behind barriers. *Developmental Sci.* 7:F1-F9

Mou Y, Province JM, Luo Y. 2014. Can infants make transitive inferences? *Cognitive Psychol*. 68:98-112

Needham A, Barrett T, Peterman K. 2002. A pick-me-up for infants' exploratory skills: early simulated experiences reaching for objects using 'sticky mittens' enhances young infants' object exploration skills. *Infant Beh. Dev.* 25:279-95

Newman GE, Herrmann P, Wynn K, Keil FC. 2008. Biases towards internal features in infants' reasoning about objects. *Cognition* 107:420-32

Olineck KM, Poulin-Dubois D. 2005. Infants' ability to distinguish between intentional and accidental actions and its relation to internal state language. *Infancy* 8:91-100

Olineck KM, Poulin-Dubois D. 2009. Infants' understanding of intention from 10 to 14 months: Interrelations among violation of expectancy and imitation tasks. *Infant Beh. Dev*. 32:404-15

Onishi KH, & Baillargeon R. 2005. Do 15-month-old infants understand false beliefs? *Science* 308:255-58

Paulus M, Hunnius S, Vissers M, Bekkering H. 2011. Imitation in infancy: Rational or motor resonance? *Child Dev.* 82:1047-57

Perner, J. 2010. Who took the cog out of cognitive science? Mentalism in an era of anti-cognitivism. In *Cognition and neuropsychology: International perspectives on Psychol. Sci*, ed PA Frensch, R. Schwarzer, pp. 241-61. Hove, UK: Psychology Press

Pinkham AM, Jaswal VK. 2011. Watch and learn? Infants privilege efficiency over pedagogy during imitative learning. *Infancy* 16:535-44

Poulin-Dubois D, Brooker I, Polonia A. 2011. Infants prefer to imitate a reliable person. *Infant Beh. Dev.* 34:303-9

Poulin-Dubois D, Chow, V. 2009. The effect of looker's past reliability on infants' reasoning about beliefs. *Dev. Psychol.* 45:1576-82

Premack D. 1990. The infant's theory of self-propelled objects. *Cognition* 36:1-16

Premack D, Premack AJ. 1995. Origins of human social competence. In *The cognitive neurosciences* ed. MS Gazzaniga, 205-18. Cambridge, MA: MIT Press

Premack D, Premack AJ. 1997. Infants attribute value +/- to the goal-directed actions of self-propelled objects. *J. Cogn. Neurosci.* 9:848-56

Repacholi BM, Meltzoff AN, Olsen B. 2008. Infants' understanding of the link between visual perception and emotion: "If she can't see me doing it, she won't get angry." *Dev. Psychol.* 44:561-4

Robson SJ, Kuhlmeier VA. 2013, April. *Selectivity promotes 9-month-old infants to encode the goals of others.* Paper Presented at Bienn. Meet. Soc. Res. Child Dev. Seattle, WA

Ruffman T. 2014. To belief or not belief: Children's theory of mind. *Dev. Rev.* 34:265-93

Schaafsma SM, Pfaff DW, Spunt RP, Adolphs R. 2015. Deconstructing and reconstructing theory of mind. *Trends Cogn.Sci*. 19:65-72

Schlottmann A, Ray ED. 2010. Goal attribution to schematic animals: Do 6-month-olds perceive biological motion as animate? *Developmental Sci.* 13:1-10

Schlottmann A, Ray ED, Surian L. 2012. Emerging perception of causality in action-and-reaction sequences from 4 to 6 months of age: Is it domain-specific? *J Exp. Child Psychol.* 112:208-30

Schwier C, van Maanen C, Carpenter M, Tomasello M. 2006. Rational imitation in 12-month-old infants. *Infancy* 10:303-11

Scott RM. 2014. Post hoc versus predictive accounts of children's theory of mind: A reply to Ruffman. *Dev. Rev.* 34:300--04

Scott RM, Baillargeon R. 2009. Which penguin is this? Attributing false beliefs about object identity at 18 months. *Child Dev.* 80:1172-96

Scott RM, Baillargeon R. 2013. Do infants really expect others to act efficiently? A critical test of the rationality principle. *Psychol. Sci.* 24:466-74

Scott RM, Baillargeon R, Song H, Leslie A. 2010. Attributing false beliefs about non-obvious properties at 18 months. *Cognitive Psychol.* 61:366-95

Scott RM, He Z, Baillargeon R, Cummins D. 2012. False-belief understanding in 2.5year-olds: Evidence from two novel verbal spontaneous-response tasks. *Developmental Sci.* 15:181-93

Scott RM, Richman JC, Baillargeon R. 2015a. Infants understand deceptive intentions to implant false beliefs about identity: New evidence for early mentalistic reasoning. *Cogn. Psychol.* 82:32-56

Scott RM, Roby E, Smith, M. 2015b. False-belief understanding in the first years of life. In *The Routledge Handbook of the Philosophy of the Social Mind*, ed. J Kiverstein. In Press

Senju A, Southgate V, Snape C, Leonard M, Csibra G. 2011. Do 18-month-olds really attribute mental states to others? A critical test. *Psychol Sci* 22:878-80

Senju A, Southgate V, White S, Frith U. 2009. Mindblind eyes: An absence of spontaneous Theory of Mind in Asperger syndrome. *Science*, 325:883-85

Setoh P, Wu D, Baillargeon R, Gelman R. 2013. Young infants have biological expectations about animals. *P. Natl. Acad. Sci. USA* 110:15937-42

Shimizu YA, Johnson SC. 2004. Infants' attribution of a goal to a morphologically unfamiliar agent. *Developmental Sci*. 7:425-30

Skerry AE, Spelke ES. 2014. Preverbal infants identify emotional reactions that are incongruent with goal outcomes. *Cognition* 130:204-16

Skerry AE, Carey SE, Spelke ES. 2013. First-person action experience reveals sensitivity to action efficiency in prereaching infants. *P. Natl. Acad. Sci. USA* 110:18728-33

Sloane S, Baillargeon R, Premack D. 2012. Do infants have a sense of fairness? *Psychol. Sci*. 23:196-204

Sodian B, Kristen SE, & Licata M. 2015. The longitudinal relation of implicit and explicit false belief understanding. Presented at Bienn. Meet. Soc. Res. Child Dev., Philadelphia

Sodian B, Schoeppner B, Metz U. 2004. Do infants apply the principle of rational action to human agents? *Infant Beh. Dev*. 27:31-41

Sommerville JA, Woodward AL, Needham A. 2005. Action experience alters 3-month-old infants' perception of others' actions. *Cognition* 96:B1-B11

Song H, Baillargeon R. 2007. Can 9.5-month-old infants attribute to an agent a disposition to perform a particular action on objects? *Acta Psychol.* 124:79-105

Song H, Baillargeon R. 2008. Infants' reasoning about others' false perceptions. *Developmental Psychol*. *44:*1789-95

Song H, Baillargeon R, Fisher C. 2005. Can infants attribute to an agent a disposition to perform a particular action? *Cognition* 98:B45-B55

Song H, Baillargeon R, Fisher C. 2014. The development of infants' use of novel verbal information when reasoning about others' actions. *PLoS ONE* 9:e92387

Song H, Onishi KH, Baillargeon R, Fisher, C. 2008. Can an agent's false belief be corrected by an appropriate communication? Psychological reasoning in 18-month-old infants. *Cognition* 109:295-315

Southgate V, Begus K. 2013. Motor activation during the prediction of nonexecutable actions in infants. *Psychol. Sci*. 24:828-35

Southgate V, Chevallier C, Csibra G. 2010. Seventeen-month-olds appeal to false beliefs to interpret others' referential communication. *Developmental Sci.* 16:907-12

Southgate V, Johnson MH, Csibra G. 2008. Infants attribute goals even to biomechanically impossible actions. *Cognition* 107:1059-69

Southgate V, Senju A, Csibra G. 2007. Action anticipation through attribution of false belief by two-year-olds. *Psychol. Sci.* 18:587-92

Southgate V, Vernetti, A. 2014. Belief-based action prediction in preverbal infants. *Cognition* 130:1-10

Spaepen E, Spelke E. 2007. Will any doll do? 12-month-olds' reasoning about goal objects. *Cognitive Psychol.* 54:133-54

Spelke ES, Kinzler KD. 2007. Core knowledge. *Developmental Sci*. 10:89-96

Stahl AE, Feigenson L. 2015. Observing the unexpected enhances infants' learning and exploration. *Science* 348:91-94

Surian L, Caldi S, Sperber D. 2007. Attribution of beliefs by 13-month-old infants. *Psychol. Sci.* 18:580-86

Surian L, Geraci A. 2012. Where will the triangle look for it? Attributing false beliefs to geometric shapes at 17 months. *Brit. J. Dev. Psychol.* 30:30-44

Thoermer C, Sodian B, Vuori M, Perst H, Kristen S. 2012. Continuity from an implicit to an explicit understanding of false belief from infancy to preschool age. *Brit. J. Dev.*

Psychol. 30:172-87

Tomasello M, Haberl K. 2003. Understanding attention: 12-and 18-month-olds know what is new for other persons. *Dev. Psychol.* 39:906-12

Träuble B, Marinović V, & Pauen S. 2010. Early theory of mind competencies: Do infants understand others' beliefs? *Infancy* 15:434-44

Träuble B, Pauen S. 2011. Cause or effect: What matters? How 12-month-old infants learn to categorize artifacts. *Brit. J. Dev. Psychol.* 29:357-74

Vierkant T. 2012. Self−knowledge and knowing other minds: The implicit/explicit distinction as a tool in understanding theory of mind. *Brit. J. Dev. Psychol.* 30:141-55

Vosniadou S, Brewer WF. 1992. Mental models of the earth: a study of conceptual change in childhood. *Cognit. Psychol.* 24:535-85

Wang S, Baillargeon R, Brueckner L. 2004. Young infants' reasoning about hidden objects: Evidence from violation-of-expectation tasks with test trials only. *Cognition* 93:167-98

Wellman HM, Cross D, Watson J. 2001. Meta-analysis of theory of mind development: The truth about false belief. *Child Dev.* 72:655-84

Wellman HM, Lopez-Duran S, LaBounty J, & Hamilton B. 2008. Infant attention to intentional action predicts preschool theory of mind. *Dev. Psychol.* 44:618-32

Wimmer H, Perner J. 1983. Beliefs about beliefs: Representation and constraining function of wrong beliefs in young children's understanding of deception. *Cognition* 13:103-28

Woodward AL. 1998. Infants selectively encode the goal object of an actor's reach. *Cognition* 69:1-34

Woodward AL. 1999. Infants' ability to distinguish between purposeful and non-purposeful behaviors. *Infant Beh. Dev.* 22:145-60

Woodward AL. 2003. Infants' developing understanding of the link between looker and object. *Developmental Sci.* 6:297-311

Woodward AL, Sommerville JA. 2000. Twelve-month-old infants interpret action in context. *Psychol. Sci.* 11:73-77

Yamaguchi M, Kuhlmeier VA, Wynn K, VanMarle K. 2009. Continuity in social cognition from infancy to childhood. *Developmental Sci.* 12:746-52

Yoon J, Johnson SC. 2009. Biological motion displays elicit social behavior in 12-month-olds. *Child Dev*. 80:1069-75

Zmyj N, Buttelmann D, Carpenter M, & Daum MM. 2010. The reliability of a model influences 14-month-olds' imitation. *J Exp. Child Psychol.* 106:208-20