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Core Knowledge and Conceptual Change

A PERSPECTIVE ON SOCIAL COGNITION

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INTRODUCTION

This century has seen an explosion of research probing infants' social cognitive capacities and propensities. The research is fueled in part by the recognition that humans, from early childhood, engage with one another in ways that are unique in the living world. Here I consider the sources of our species' social talents. According to one family of accounts, we have distinctive, innate capacities for forming new concepts and systems of knowledge in any domain, including the social domain (e.g., Carey, 2009). According to a second family of accounts, we have innate, specifically social talents and proclivities (e.g., Csibra & Gergely, 2009; Dunbar, 1998; Meltzoff, Kuhl, Movellan, & Sejnowski, 2009; Premack & Premack, 1995; Tomasello, 1999, 2009). To evaluate these accounts, I ask what infants' beginning social concepts might be. To set the stage, I first outline some of the ideas and findings that animate the two approaches to human social cognitive development.

CORE KNOWLEDGE AND COMPOSITIONAL CAPACITY

Human perceptual and action capacities are highly similar to those of other animals, but our cognitive achievements are unique; we alone create new systems of knowledge (such as computer science) and restructure older knowledge systems (such as physics) by forming new concepts. What capacities underlie these achievements? I believe research provides evidence for a small set of domain-specific cognitive systems that serve as the foundations for all our knowledge, including core systems of object cognition, numerical cognition, and spatial cognition. In addition, we are endowed with a domain-general system, unique to our species, that serves to represent, and combine productively, the outputs of the core systems (Spelke, 2011).

The domain-specific systems have five key properties. First, they are limited; each operates on restricted inputs, delivers restricted outputs, and supports a small but critical set of inferences. A core place system, for example, represents extended surfaces but not objects; it computes the distances and directions of surfaces but not the angles at which surfaces meet; and it supports inferences concerning one's own position and heading but not inferences about the shapes or relative positions of objects (Spelke & Lee, 2012). Second, the systems are shared by other animals. For example, chicks and fish show the same signature limits as children in their representations of places, suggesting that the place system evolved in ancestors common to humans and other animals (Gallistel, 1990; Spelke & Lee, 2012). Third, the systems are innate; they arise independently of our encounters with the entities that they serve to represent, and independently of our experiences with the tasks they serve to accomplish. For example, human infants show sensitivity to auditory–visual numerical correspondences, likely the very first time they view a visual array of 4 or 12 similar objects (Izard, Sann, Streri, & Spelke, 2009), and controlled-reared chicks analyze the geometric structure of a spatial layout the first time that they encounter such a layout (Chiandetti, Spelke, & Vallortigara, 2014). Fourth, the systems exist and function throughout life. For example, the core number system found in infants is central to the intuitive reasoning of people of all ages (Dehaene, 1997) and in all cultures (e.g., Dehaene, Izard, Pica, & Spelke, 2006). Finally, each system connects in some way to children's later cognitive achievements. For example, the robustness of core number representations at 6 months of age predicts children's mastery of number words at 3.5 years (Starr, Libertus, & Brannon, 2013b), and activities that exercise that system enhance performance of symbolic arithmetic in adults (Park & Brannon, 2013) and children (Hyde, Khanum, & Spelke, 2014). These findings suggest that the domain-specific systems found in infants serve as foundations for later learning and reasoning.

Nevertheless, even the most basic systems of concepts that humans can articulate explicitly—including object kinds, the positive integers, and the points, lines, and figures of Euclidean geometry—are far more powerful than any system of core knowledge (Carey, 2009). For example, Euclidean plane geometry captures fundamental relationships between distance and angle, but no core system of geometry serves to represent both of these properties (Spelke & Lee, 2012). In general, mature human concepts capture rich information about the world, organize that information into a unitary, interconnected web of belief, and make that information available to serve a wide array of purposes.

I hypothesize that children create new systems of concepts by combining information from diverse domains of core knowledge. In the case of number and geometry, these combinations first are manifest at the time that children master their native language. For example, children use concepts of *one, two,* and *three* as they master language expressions that quantify over object kinds (*two shoes* designates an array composed of a shoe and another shoe) and map approximate number representations to those expressions (*two shoes* designates a quantity of shoes larger than one and smaller than three). Then children express larger, exact numbers by using their known number words to form new expressions (e.g., "three shoes and two more" and "three pairs of shoes"). Because the rules of language are productive, such natural language expressions can, in principle, designate any of the natural numbers.

This example suggests that our species-unique capacity for creating new systems of concepts connects to our equally distinctive capacity for learning and using a natural language. Children's attainment of the natural number system presents a genuine conceptual advance, because each integer concept extends beyond the limits of any single system of core knowledge. Nevertheless, the rules and principles that allow for the linguistic expression of concepts such as *three* and relations such as *two more* are widespread across human languages and likely universal (though c.f. Frank, Everett, Fedorenko, & Gibson, 2008). Natural number concepts, therefore, may be shared by all people with sufficient access to a natural language (though perhaps not by people who lack such access—see Spaepen, Coppola, Flaherty, Spelke, & Goldin-Meadow, 2013; Spaepen, Coppola, Spelke, Carey, & Goldin-Meadow, 2011). It is even possible that children come to grasp the fundamental logic of natural number—that numbers are composable from other numbers by addition and multiplication—by learning the words and rules of their native language and applying those rules to number words. Such a possibility might explain why people who lack any formal education, and whose culture does not provide any counting routine, come to have these concepts (Izard, Pica, Spelke, & Dehaene, 2008; Izard, Streri, & Spelke, 2014).[1]

Thus, it is possible that children develop new systems of knowledge by mapping representations from core knowledge systems to the words and expressions of their native language. Language learning may make new concepts available, because the words of a language link together information from distinct systems, and because the rules that form larger expressions are recursive and domain-general; they are conditioned only by the grammatical properties of words and expressions, not by their conceptual content. Concepts that are constructed on the basis of language expressions can thus be abstract (they can apply to anything we can articulate), accessible (they can be used for any purpose we can devise), and powerful (because they can be composed to form infinitely many new concepts).

Regardless of the role that they assign to language, conceptual combination hypotheses propose that our early-developing, foundational cognitive systems are substantially the same as those of other animals, but that we alone combine the products of these systems rapidly, flexibly, and productively to form new systems of knowledge. Nevertheless, research on conceptual change has focused primarily on case studies with parallels to the history of mathematics and science (Carey, 1985, 2009). In contrast, few case studies of conceptual change have been conducted in the domain of social cognition. That gap is significant, because a compelling family of hypotheses supports a different picture of human social cognitive development.

UNIQUELY HUMAN CAPACITIES FOR SOCIAL COGNITION

Many contemporary thinkers propose that our unique cognitive accomplishments stem from a set of species-unique social cognitive capacities and motives. Humans may be predisposed to teach and learn from one another, gaining knowledge far beyond our direct experience (Csibra & Gergely, 2009; Meltzoff et al., 2009; Premack & Premack, 1995; Tomasello, Kruger, & Ratner, 1993). We may be predisposed to cooperate with one another both extensively and flexibly, accomplishing a wide range of tasks that no single person could perform (Tomasello, 2009). To this end, we may have unique cognitive capacities for forming and keeping track of large and differentiated social groups (Dunbar, 1998) marked by cultural norms that perpetuate the group and its traditions, skills, and knowledge (Tomasello, 1999). According to these views, it is our special talents in the social domain, rather than any general combinatorial capacity, that distinguishes us from other animals. Indeed, Tomasello has proposed that natural language itself develops as a consequence of our inherent, uniquely human social predispositions (e.g., Tomasello, 2003).

Recent research in developmental psychology bolsters this proposal, as children display species-unique social cognitive abilities long before they display any such abilities in the domains of science or mathematics. By the end of the first year, infants communicate with others by sharing attention to objects (Tomasello, 2008). Before their second birthday, children spontaneously help others to complete their goals and engage in joint collaborative actions (see Warneken & Tomasello, 2014). Before starting school, children become adept at learning from others (see Harris, 2012), outperforming all other animals in their mastery of culture-specific actions and artifacts (e.g., Horner & Whiten, 2005). This learning may extend to actions such as counting and artifacts such as clocks, calendars and rulers—devices that both require and support children's number concepts. Thus, our species' unique aptitude for social reasoning might propel our achievements in all other domains.

Nevertheless, the clearest evidence for uniquely human social cognitive capacities comes from studies of older infants and toddlers. Thus, this research does not reveal the developmental origins of children's social talents. For insights into those sources, I turn to studies of younger infants.

EARLY SOCIAL COGNITIVE DEVELOPMENT

Research on young infants presents a complex picture of our earliest social cognitive capacities, with puzzling gaps and inconsistencies. Although 1-year-old infants monitor their social partners' attention to objects (Tomasello, 2008), younger infants neither do

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this nor discern the objects of other people's gaze (Brooks & Meltzoff, 2005; Phillips, Wellman, & Spelke, 2002; Woodward, 2003). In some experiments, young infants appear to represent other people's perceptions and beliefs, even when those mental states differ from their own (Kovacs, Teglas, & Endress, 2010; Luo & Johnson, 2009). Other experiments using similar measures, however, show no evidence for this ability until the second year (e.g., Onishi & Baillargeon, 2005) or beyond (e.g., Clements & Perner, 1994).

Most dramatically, some experiments suggest that very young infants are sensitive to helping: After watching a protagonist character struggle to climb a hill or open a box containing a desired toy, for example, infants respond positively to a character who helps the protagonist by pushing him up the hill or opening the box, relative to a character who hinders him (e.g., Hamlin & Wynn, 2011; Hamlin, Wynn, & Bloom, 2007). In other experiments, however, much older infants fail to understand the purpose of acts such as opening a box so as to gain access to an object inside it, even when those acts are performed by a single agent (Woodward & Sommerville, 2000). Moreover, infants show little ability to determine which of two actions will be helpful to a protagonist, even in the simplest contexts.

In one study, for example, an actor reached repeatedly and consistently for one member of a pair of objects (e.g., a bear rather than a ball). Then both objects were moved out of the actor's reach and view but remained accessible to the infant. When the actor asked for help in obtaining the desired object, 14-month-old infants readily handed her one of the objects, demonstrating the ability and motivation to help her, but they chose between the objects at random (Hobbs & Spelke, 2015). Further studies showed that the infants correctly inferred that the actor's goal was the bear (as do younger infants: Woodward, 1998), and that they gave her the desired object when she reached for it directly but unsuccessfully. Nevertheless, the infants failed to infer that the more helpful action was to give her the bear when that inference required that they take account of the preference she demonstrated by her prior goal-directed action. Children do not succeed at this task until their second birthday, and they fail a similar, more natural task until 3 years of age (Hobbs & Warneken, in review). How can infants be so sensitive to distinctions between helpful and unhelpful actions in some circumstances, and so insensitive to these distinctions in other, seemingly simpler situations?

In research on early cognitive development, such inconsistencies often are revealing. In studies of numerical cognition, for example, infants presented with some type of displays successfully compare arrays of two vs. three objects but fail to compare arrays of one vs. four objects (Feigenson, Carey, & Hauser, 2002), whereas infants presented with other displays detect the latter numerical difference with greater ease than the former (Starr, Libertus, & Brannon, 2013a). These findings point to the contours of the distinct and limited systems by which infants represent numerical information (Carey, 2009). Could inconsistent patterns of reasoning in the social domain similarly reveal the contours and limits of core social cognition?

Here I consider whether an account of social cognitive development, centering on distinct and limited systems of core knowledge that come to be productively combined, can explain children's developing capacities for sharing attention to objects, for communication, and for the social cognitive achievements that follow, including pedagogical learning, cooperation, moral evaluation, and mental-state inferences. I suggest that two core systems support infants' reasoning about people, their behavior, and their mental states. One system represents people as *agents* who cause their own motion and act intentionally on objects. The other system represents people as *social beings* who engage with other social beings and share phenomenal states of attention and emotion. Each system, I hypothesize, is ancient and limited: It is shared by other animals, and it supports understanding of only a small subset of the social interactions and relationships that older children master. Our unique social cognitive achievements depend on our capacity for combining these initial agent and social concepts with one another and with concepts from other core domains.

In the rest of this chapter, I consider the core agent and social systems in turn. Then I sketch briefly how these systems might be productively combined to form a new and more powerful system of knowledge of people, their actions, and their mental states.

CORE KNOWLEDGE OF AGENTS

A wealth of research provides evidence that infants aged 6 to 12 months represent agents as entities that cause their own motion and direct their actions to objects. When presented with a body that either has a face or engages in apparently spontaneous forward motion in a consistent facing direction, they infer that the body is self-propelled (Csibra, Biro, Koos, & Gergely, 2003; Pauen & Träuble, 2009). If such a body encounters an object, infants expect that it will not pass through it (self-propelled objects, like inanimate objects, are solid); instead, it will cause changes to the object's motion or state on contact (Muentener & Carey, 2010). If an agent moves consistently to an object, choosing that object over others, infants represent the agent's motion as a goal-directed action (Woodward, 1998).

As the goal of an action is identified, infants also expect that an agent will pursue its goal efficiently, taking the least effortful, unobstructed path to the goal object (Gergely, Nádasdy, Csibra, & Bíró, 1995). If an agent first is seen to reach to an object by circumventing an obstacle and then the obstacle is removed, infants expect the agent to reach to the object on a new and more direct path (Brandone & Wellman, 2009). Finally, in predicting and interpreting an agent's actions, infants take account of the agent's perceptual access to objects. If an object is occluded from an agent's perspective, infants do not expect the agent to approach it (e.g., Luo & Johnson, 2009). Conversely, if an object lies within the agent's perceptual field, infants expect the agent to adapt its motion accordingly, moving efficiently toward the object if it is the agent's goal and circumventing the object if it stands in the way of a different goal object (Csibra et al., 2003; Luo & Baillargeon, 2010).

An experiment by Saxe, Tenenbaum, and Carey (2005) provides the clearest evidence for domain-specific reasoning about agents. Ten-month-old infants first explored an inanimate object—a beanbag. Then on a series of trials, they saw the beanbag fly over a barrier on a puppet stage. On different trials, the height of the barrier varied, and the path of the beanbag was efficiently adapted to it. Thus, infants saw motion that was goal-directed and efficient, displayed by a manifestly inanimate object. The authors asked whether infants would posit an unseen agent behind the stage as the cause of the beanbag's motion, by testing infants with events in which a hand appeared from behind one or the other side of the stage. Infants' looking patterns provided evidence that they expected the hand to emerge where the beanbag's motion began. Interestingly, infants did not show this expectation when a train (a moveable but inanimate object) replaced the hand, or when an autonomously moving puppet replaced the inert beanbag: Infants posited a distinct, animate causal agent to explain the efficient, goal-directed movement of an inanimate object, but not of another autonomous agent.

Thus, 6- to 12-month-old infants represent agents' actions as autonomously generated, goal-directed, efficient, perceptually guided, and causally efficacious; but what are the origins of these capacities? Under some conditions, infants reason about actions only after they begin to perform them. In particular, infants come to view acts of reaching for objects as goal-directed when they start reaching for objects (between 4 and 5 months) and they come to view acts as guided by second-order goals (e.g., pulling on a cloth to retrieve a distant object that sits on it) when they start engaging in such actions (between 8 and 12 months: Sommerville & Woodward, 2005). Children surely need to learn which motions by an agent are goal-directed actions (like sewing) and which are unintended side effects (like pricking one's finger: Woodward, 1999). Do the abilities just described also depend on local and piecemeal learning about actions and their properties, or do they spring from a unitary core system of knowledge?

Fortunately, most of these abilities are found in other animals, whose own action capacities develop more precociously and who can be tested under conditions of controlled rearing. Apes and monkeys represent reaching actions as goal-directed and perceptually guided (Marticorena, Ruiz, Mukerji, Goddu, & Santos, 2011). Newly hatched chicks represent agents as causing both their own motions and the motions of other objects, and they do so on first encountering a visible agent (Mascalzoni, Regolin, & Vallortigara, 2010). Monkeys use information about another agent's perceptual access to an object to make inferences about their likely actions on that object, as do infants (Flombaum & Santos, 2005) and chicks (Salva, Regolin, & Vallortigara, 2007). These findings suggest both that other animals share the limited knowledge of agents found in young human infants and that some of that knowledge is present at the time when an animal first encounters other agents and engages in its first acts of reasoning and learning about them.

Nevertheless, some key aspects of infants' reasoning about agents and their actions have not been studied in other animals, to my knowledge. In particular, does the principle of efficiency—that agents will tend to select the most efficient action that achieves their goal—serve as a guide to infants' earliest action understanding? Recent studies provide ways to address this question, by using training methods with young human infants.

In studies by Sommerville, Woodward, and Needham (2005), 3-month-old infants (who cannot yet reach for and grasp objects) were given Velcro mittens that allowed them to pick up objects and displace them. When the infants later viewed events in which another person reached for one of two objects, they represented the reaching as directed to the goal object. Because infants without the mittens experience did not show this expectation, infants evidently learned to perceive this reaching action as goal-directed. Although infants' ability to attribute goals to agents who reach for objects normally emerges 1–2 months later, it evidently can be collapsed through a brief manipulation in the lab. But what do infants learn from wearing the mittens, and what do they already understand about agents and their actions? In particular, do infants learn, by acting on objects, that agents will tend to act efficiently?

Research by Amy Skerry addressed this question (Skerry, Carey, & Spelke, 2013). Three-month-old infants were allowed to play briefly with an object while wearing Velcro mittens. During this period, no other object stood on the table, so infants picked up and displaced the object directly. Then they viewed events in which an agent reached over a barrier of variable height, adapting her trajectory to the height of the barrier, and picked up an object on its far side. To test whether the infants expected the agent to act efficiently, the barrier was removed and the agent alternately moved to the object on a direct, straight path or on a familiar, circuitous path. Infants in the Velcro mittens condition (but not in other conditions involving no mittens experience or experience with mittens lacking Velcro) behaved like older infants: They looked longer at the inefficient, circuitous action. Importantly, this pattern was only shown by infants who viewed efficient, goal-directed actions during familiarization; if the action presented at familiarization occurred with the barrier placed behind the goal object, such that the curvilinear reaching action was inefficient from the start, then infants given Velcro mittens experience, like older infants, did not expect direct reaches to the object at testing. Thus, the infants with the mittens experience did not simply expect that the agent would reach for objects on straight paths. Instead, they expected goal-directed and efficient action only when the curvilinear motion was an efficient response to a barrier.

These findings suggest that infants' own action experience helps them to individuate actions, perhaps by enhancing their abilities to determine which of the movements of other agents are intentional actions, rather than passive motions, reflexive behaviors, or unintended byproducts of other actions. Infants' experience with the mittens could not have taught them, however, that actions are efficient and constrained by barriers, because the infants had no experience with barriers to direct reaching during the experiment. These infants also could not have learned about efficient ways to circumvent barriers through their earlier reaching experiences because they do not yet reach for objects. Knowledge of action efficiency thus develops prior to infants' own reaching experiences. Nevertheless, these studies leave open the possibility that this knowledge develops in 3-month-old infants through earlier experiences of other kinds. Studies of newborn infants or of controlled-reared animals could probe its sources further.

Infants' early knowledge of agents appears to be organized into an interconnected whole: Given information that a person is engaged in an action, infants infer that the action is goal-directed, constrained by obstacles, and efficient. Nevertheless, young infants' understanding of agents is limited. Infants older than 9 months can represent agents as acting on objects when their actions are indirect and imply second-order goals (e.g., when an agent opens a transparent box so as to obtain an object that it contains), but young infants only represent the first-order goals of direct actions (e.g., opening the box; Woodward & Sommerville, 2000). Infants in the second year use information about an agent's direction of gaze in predicting and interpreting his or her actions, but younger infants do not; they use information about occlusion from an agent's visual perspective (e.g., Kovacs et al., 2010) but not gaze (e.g., Phillips et al., 2002; Woodward, 2003).

Moreover, infants as young as 7 months of age distinguish successful from failed goal-directed actions (Hamlin, Hallinan, & Woodward, 2008) and are attentive to displays of emotion (Walker-Andrews, 1997), but they show limited expectations that agents will be happy when their actions are successful and unhappy when they fail (Hepach & Westerman, 2013; Skerry & Spelke, 2014). Although infants may endow agents with intentions, goals, and preferences (i.e., mental states construed as intentional relations to objects), they may fail to endow agents with emotions and other phenomenal experiences (i.e., mental states with phenomenal, shareable content). Finally, young children often imitate the goal-directed actions of others, thereby learning conventional ways of acting on objects, but infants younger than 9 months do not; they imitate the communicative gestures of other people but not their actions on objects (Meltzoff, 1988).

In summary, research suggests that a core system of agent representation, distinct from other core systems, emerges early in infancy. This system serves to represent the actions of agents as efficient, goal-directed, intentional, and causally efficacious, provided that infants can identify an action and its goal. This system, however, shows poor prospects as the sole source of our uniquely human cognitive accomplishments, both because it likely is shared by other animals and because it is critically limited with respect to its domain of application (e.g., to direct but not indirect actions), the information it detects (e.g., occluders but not closed eyes that block an agent's visual access to objects), the representations it constructs (e.g., mental-state representations of goals and intentions but not of emotions), and the functions it performs (predicting and interpreting agents' actions on objects, but not using such actions to determine how to help an agent to achieve his or her goal).

At this point, readers may object. Young infants are highly sensitive to gaze in some contexts. When they observe or interact socially with others, they sometimes respond appropriately to expressions of emotion. When they observe acts of helping, even 5-month-old infants appear to represent indirect actions as guided by second-order goals; they seem to understand that an agent who unsuccessfully tries to open a closed box aims to obtain the object it contains, and that a second agent, who opens the box, helps him or her achieve that goal (e.g., Hamlin & Wynn, 2011). Moreover, infants engage in appropriate social or moral evaluations of helpers and hinderers, evaluations that suggest they understand helpful and cooperative actions as both instrumental and social (see Hamlin, 2013). These abilities, ~~I suggest, are~~ supported by a different system of core knowledge.

CORE KNOWLEDGE OF SOCIAL BEINGS

From birth, humans are social. Young infants attend to faces, use subtle features to distinguish one face from another (Pascalis, de Haan, & Nelson, 2002), and look longer at faces that look directly at them (Farroni, Csibra, Simion, & Johnson, 2002). If a person looks at an infant and then opens his mouth or protrudes his tongue, the infant behaves in ways suggestive of imitation (Meltzoff & Moore, 1977; c.f. Ray & Heyes, 2011). If the person looks first at the infant and then to the side, the infant will move her attention to the same side of the scene (e.g., Hood, Willen, & Driver, 1998); infants automatically coordinate their own state of attention to that of their social partner. Finally, if the person vocalizes or gestures visually in a manner suggestive of an emotion, the infant may respond with expressions suggesting the same emotion (e.g., Field et al., 1983).

None of these behavior patterns is unique to humans. For example, monkeys are highly attentive and sensitive to faces from birth, look longer at faces with direct gaze, and follow gaze to objects (Paukner, Simpson, Ferrari, Mrozek, & Suomi, 2014). Monkeys imitate the facial gestures of those who look at them (Ferrari et al., 2006), and they are sensitive to emotional expressions and respond with appropriate expressions of their own (Simpson, Paukner, Sclafani, Suomi, & Ferrari, 2013). Like human infants, infant monkeys engage with their mothers in face-to-face interactions (Ferrari, Paukner, Ionica, & Suomi, 2009). Perhaps most surprising, newborn human and monkey infants are equally attentive and responsive to faces of both these species; preferences for faces of their own species develop later in infancy, and the direction of those preferences depends on social and visual experiences, in both species (Scott & Monesson, 2009; Sugita, 2008). All these findings suggest that capacities for face recognition, imitation, and processing of gaze and emotion are shared across primates.

Debates abound concerning the nature and sources of these capacities. Some argue that each of these behavior patterns is automatic and reflexive, and that true imitation and other social actions emerge by learning from rich social experience (e.g., Ray & Heyes, 2011). Such reflexes might well have evolved to promote infants' survival and care, and they might be both distinct from each other and discontinuous with later-developing social cognitive abilities. Alternatively, all these abilities might spring from a unified system of core social knowledge. Just as agents have one fundamental property (they act on objects, causing changes in the world), social beings may have one fundamental property: They engage with other social beings, sharing phenomenal states. When a person looks at, speaks to, or imitates an infant, the infant may perceive the person as engaging with him, and he may respond to his social partner by performing the same gestures and entering into common mental states of attention and emotion. A unitary system for engaging with others could explain why newborn infants imitate the gestures of a person who looks at them, why infants' attention shifts in response to the shift in such a person's gaze, and why infants tend to respond in kind to their social partners' expressions of emotion.

This hypothesis is difficult to test using methods that focus on infants' first-person interactions with real people or with high-fidelity videos or photographs. Because such displays are rich in information, highly familiar, and have been reliable signals of social engagement throughout primate evolution, it is hard to know whether infants' responses to these displays reflect a unitary and general conception of social beings or diverse, local, learned, or evolved expectations triggered by specific displays. The hypothesis can be tested, however, through experiments that allow infants to observe the social interactions of animated characters who behave in novel ways. Rich and systematic experiments using these methods and displays have been conducted in multiple laboratories, illuminating diverse aspects of early social cognitive development (e.g., Gergely et al., 1995; Johnson, Dweck, & Chen, 2007; Premack & Premack, 1995; Thomsen, Frankenhuis, Ingold-Smith, & Carey, 2011). If infants have a unitary and general system of core social cognition, then they may expect that social beings who engage with one another will align with their behavior, and they may apply these expectations to superficially unfamiliar social events. Research with Lindsey Powell begins to test these predictions (Powell & Spelke, 2013a).

These studies present infants with simplified social characters (colored geometric forms with schematic faces) that move both together and individually. In one study (Powell & Spelke, 2013a), two groups of three characters each appeared in a display with two boxes. The three members of each group danced together in alternation, and then all the characters faced forward, two members of one group circled one box, and two members of the other group circled the other box. Then, at the test, the remaining member of each group alternately circled the *same* box; thus one character copied the motion of its own group, whereas the other did not. Infants looked longer when the third group member's motion was incongruent with its group, suggesting that they expected the members of each group to act alike. Further studies using this method showed that this expectation was specific to animate characters that interacted socially: The effects disappeared if cues to animacy were removed or if animated characters failed to interact with each other. Thus, infants expect aligned actions from socially interactive characters, but not from grouped objects or socially unrelated agents.

We next asked whether infants expect social beings to approach the characters whose actions they imitate (Powell & Spelke, 2013b). Infants were introduced to two pairs of characters and a fifth character centered between them. On familiarization trials, each pair performed a different novel action and the fifth character responded to the pair, in turn, by performing just one of the actions, thus imitating one group and not the other. When, on test trials, the fifth character alternately approached and danced with the two groups, 12-month-old infants looked reliably longer at the incongruent actions (dancing with the nonimitated group), and 4-month-old infants showed the opposite preference. The latter effect was replicated in studies replacing the group-specific motions with sounds: 4-month-old infants again looked longer when the fifth character approached the group whose sound he had copied. Following Kidd, Piantadosi, and Aslin (2012), we reasoned that events involving five characters place high demands on young infants' memory, reducing their confidence in their social predictions and enhancing attention to test events that confirm those predictions (see also Powell & Spelke, 2013a, Experiments 4 and 5). Consistent with that hypothesis, a further experiment, presenting 4-month-old infants with the same copying events performed by three characters, revealed a trend toward longer looking at the incongruent approach events (Powell, 2012). Thus, infants across a wide age range expect social characters to affiliate with the characters whose actions or sounds they copy, although older infants detect these cues to affiliation with greater ease.

We next asked whether young infants expect social beings to affiliate with their imitators. Imitation evokes affiliative motives in children (Agnetta & Rochat, 2004), adults (Chartrand & Bargh, 1999) and even monkeys (Paukner, Suomi, Visalberghi, & Ferrari, 2009). To test whether infants attribute such motives to social characters who are imitated, we reversed the roles of the actors in the above studies presenting imitative interactions. At the test, therefore, the targets of imitation—alternately approached the characters who were or were not their imitators. In these experiments, infants showed no expectation that targets of imitation would affiliate with their imitators (Powell & Spelke, 2013b). We conclude that young infants have asymmetric expectations about imitative interactions: They expect imitators to affiliate with their targets, but not the reverse.

These findings suggest two key limits to young infants' reasoning about imitation and social affiliation. First, adults and older children expect social group members to conform to the norms of their group, and we often interpret imitative behaviors as caused by social forces that promote conformity (see Tomasello, 2009). Infants may lack this expectation, because such forces would apply to imitators and targets alike. Second, social beings (infants included) like people who imitate them; thus, the imitative actions that infants experience and observe will tend to elicit prosocial actions and feelings in their targets. Nevertheless, infants may not expect imitative actions to have this causal effect on other social beings. If they did, they should expect those who are imitated to affiliate with their imitators.

These considerations suggest that infants interpret imitation as a *sign* of social engagement and prosocial motives in the imitator, but that they fail to view imitation either as caused by social forces or as causing prosocial motives in others. More generally, infants may fail to view the gestures by which social beings engage with one another as causally efficacious actions. This last suggestion is bolstered by the findings of studies of infants' responses to imitative actions on objects. Nine-month-old infants detect when another person imitates their own action on an object, but they do not respond to this copying with smiling and other signs of social engagement as do older infants (Agnetta & Rochat, 2004; Meltzoff, 1999). Moreover, such infants expect characters who affiliate with one another to imitate their movements of jumping or sliding if those movements have no apparent instrumental purpose, but they fail to expect imitation if these same movements result in contact with an object and cause changes in the object, changes that suggest that the imitator's action was guided by an instrumental goal (Powell, Schachner, & Spelke, 2014). Young infants may interpret imitative actions either as social or as instrumental, but not as both at once.

Contrary to this suggestion, studies of infants' preferences for social beings who help others do appear to provide evidence that infants view the actions of social beings as guided by both instrumental and social goals (Hamlin, Wynn, & Bloom, 2007, 2010). When one agent tries and fails to accomplish an instrumental goal (climbing a hill, or opening a box to obtain an object) and a second character helps him (by pushing him up the hill or opening the box with him), young infants prefer the helpful character to a third character who hinders the agent (by pushing him down the hill or slamming the box shut). Beginning at 3 months, infants look selectively at the helpful character; beginning at 6 months, they also reach for the helpful character. These findings suggest that infants understand and value acts of helping—instrumental acts guided by second-order social goals.

Powell (2012) notes, however, that helpful and cooperative actions often involve reproduction of others' actions, and they did so in the helping scenarios presented to young infants (although see Hamlin, Ullman, Tenenbaum, Goodman, & Baker, 2013, for a study with older infants that dissociated helping from imitation). In each scenario, the action of the helper copied the previous action of the character that he helped, whereas the action of the hinderer did not. Like the character who attempted to climb the hill, the helper moved up the hill whereas the hinderer moved down; like the character who pulled upward on the box in a vain attempt to open it, the helper pulled upward whereas the hinderer pushed downward. If young infants fail to understand helping actions as instrumental behaviors guided by second-order social goals, might they view these imitative actions as social gestures? If so, then young infants may value helpers because they detect and value those who imitate others.

To test this possibility, we showed 12-month-old infants animated events based on those in Hamlin et al.'s (2007) study, in which a character successfully climbed to a plateau at the center of a hill and then repeatedly attempted, and failed, to climb from the plateau to the top of the hill (Powell & Spelke, 2014). After this event, the character moved to one side of the plateau and remained stationary while two other characters alternately moved either up the plateau (the imitator) or down the plateau (the non-imitator). These motions were similar to those of the helper and hinderer in the original study, but they had no effect on the agent, who stood motionless outside their path; thus they preserved the imitative aspects of the actions but not their helpful effects. When infants were given a reaching preference test, following Hamlin's procedure, they reached selectively for the imitator. Thus, a preference for imitators might account for infants' preferences for helpful actors.

The infants in this experiment were 12 months old, and so their preference for imitators might have developed late in the first year, as a consequence of their rich social experience with others who imitate them. To test whether young infants prefer social characters who imitate other characters to those who do not, we returned to studies of 4-month-old infants, using the animated events in which a lone character made one of two sounds, and two other characters responded to him by producing either the same sound (the imitator) or a different one (Powell & Spelke, 2014). When infants were shown 3D versions of the latter two characters in a looking preference test modeled on Hamlin et al.'s (2010) test, they looked longer at the character who had imitated the lone character's sound, an action suggesting that they preferred the imitator. In contrast, experiments reversing the order of the above imitative interactions provided no evidence that infants prefer the targets of imitation to non-targets. These findings, replicated in further studies, suggest that infants' preference for imitators does not stem from a preference for social beings whose actions are more familiar or more similar to those of other social beings, as these properties are as true of targets as of imitators. We suggest that infants prefer imitators because their acts of imitation signal that they are attentive to their social partners and invested in their behavior. This preference should lead young infants to prefer helpers to hinderers in any situation in which a helper's actions are similar to those of the individual whom she helps, as in the experiments of Hamlin et al. (2007, 2011).

In summary, these findings lend credence to the hypothesis of a core system of social knowledge. Such a system can account for young infants' attention and responsiveness to their own social partners, and for infants' expectations of and preferences for social beings whose interactions they observe as third parties. Infants appear to represent other social beings as capable of engaging with other social beings. They interpret imitation by social beings (but not the same repetition of motion by inanimate objects or nonsocial agents) as a sign of social attention and commitment. They also expect a social being who imitates another social being to affiliate with her target, and conversely expect social beings who have affiliated with one another to imitate their partners' actions. Finally, studies of infants' first-person social interactions hint that infants may interpret direct gaze, imitation, and other social behaviors as attempts to communicate and share mental states of attention and emotion.

Like other core systems, the core system of social knowledge appears to have pronounced limits. In contrast to older children, young infants may not expect social beings to affiliate with similar others or to behave in accord with social norms—at least, such expectations are not engendered by acts of imitation. Above all, infants may not endow social beings with the power to cause changes in the behavior or mental state of the beings with whom they engage. Although adults and children use imitation to increase their social partner's liking for them, infants do not appear to expect imitation to have this effect, as they expect imitators to affiliate with their targets but not the reverse. More generally, infants may endow social beings with experiences of attention and emotion but not with causal powers.

In this respect and others, young infants' reasoning about people as social beings appears to differ from their reasoning about people as agents. Agents act on objects, causing changes in those objects, but social beings engage with other social beings, expressing their mental states of attention, emotion, and commitment. The actions by which agents cause changes in objects are as efficient as possible, but the most common gestures by which social beings engage with others are inefficient: We signal our engagement by means of otherwise purposeless actions such as waving a hand or dancing (see also Schachner & Carey, 2013). For infant observers, agents' actions on objects are predictable from their visual access to objects (the presence or absence of occlusion) but not from their direction of gaze, whereas social beings' states of engagement appear to be signaled by their gaze direction, at least in first-person social encounters, from birth (e.g., Farroni et al., 2002).

Most tentatively, infants appear to interpret the behavior of agents who act on objects as guided by goals and intentions, but they may interpret the behavior of social beings who engage with other social beings as expressive of shareable phenomenal states of attention and emotion. In these last interpretations, we may see the germs of two distinct conceptions of mental states, as intentional relations to objects and events and as phenomenal experiences that can be shared by social partners. These two conceptions continue to have dissociable effects in studies of adults (Gray, Gray, & Wegner, 2007; Knobe & Prinz, 2008). Thus, distinct systems for representing agents and social beings may originate in infancy and remain partly distinct throughout life. These distinct systems may have evolved in distant ancestors, because effective actions on inanimate and animate objects differ fundamentally (Gelman & Spelke, 1981).

The contrast between infants' reasoning about object-directed actions vs. socially directed gestures is especially striking, because the most important and familiar agents *and* social beings for young infants are the same individuals: the people who care for them. Infants are immersed in experiences in which one and the same person displays social and instrumental actions. Nevertheless, infants appear to interpret people's instrumental and social actions in distinct ways. Moreover, limits to attention and working memory may prevent young infants from representing a single action as both social and instrumental, even when it is (as, for example, when a person looks and smiles at them while presenting them with a toy). At any given moment, young infants may construe other people either as agents or as social beings, but not as social agents (Powell et al., 2014).

BEYOND CORE SOCIAL KNOWLEDGE

Infants' social behavior begins to undergo dramatic changes at the end of the first year. By 12 months, infants communicate by pointing to objects and by alternating their attention to their partner and to objects (e.g., Liszkowski, Carpenter, & Tomasello, 2008). They also begin to learn from the communications and actions of others (e.g., Agnetta & Rochat, 2004), to collaborate with and help others (e.g., Warneken & Tomasello, 2014), and to understand the conflicting instrumental behaviors of agents as reflective of their relative positions within a social hierarchy (e.g., Thomsen et al., 2011). Later, children develop an understanding of their own and others' mental states and of social norms, and they come to use this understanding to explain and evaluate their own actions and those of others (e.g., Tomasello, 2009). All of these developments are unique to humans and broadly shared across human cultures.

I believe that all these changes depend on a capacity to combine productively core representations of agents and social beings so as to form a new, uniquely human system of concepts of *social agents*—causally efficacious social beings. Social agents engage in instrumental actions to fulfill social goals: They act to help or hinder the instrumental actions of others, they inform others about objects, and they offer objects as gifts that express and enhance their affiliation. Social agents also engage with one another to achieve instrumental goals: They communicate and cooperate so as to better comprehend and transform the material world. Because the actions of social agents have social consequences and are guided by social intentions, those actions are morally evaluable. To understand and evaluate the actions of social agents, children must develop a conception of mental states both as intentional relations to objects and as shareable experiences.

If the core agent and social systems exist in other animals, then animals will be able to link specific actions and social gestures in a limited, piecemeal manner. Some direct links between social gestures and instrumental actions arise by means of associative learning (as, for example, when a dog interprets a person's waving of a ball as a sign that he is about to throw the ball). Other direct links between agent and social representations are innate in animals (for example, the performance of instrumental actions in courtship displays). Young infants also learn associative relations between social gestures and object-directed actions; such learning may lead infants to predict future object-directed actions from the direction of an actor's gaze, and therefore to follow the actor's gaze to the object, before infants develop any general understanding of gaze as object-directed (Woodward, 2003). At the end of the first year, however, infants begin to combine their knowledge of agents and social beings productively to form an integrated system of knowledge. Like Premack, Meltzoff, Tomasello, Gergely, and Csibra and others, I believe this system is unique to our species. I suggest, however, that its construction depends on the same combinatorial system that gives rise to new concepts of objects, number, and geometry.

A system of knowledge of social agents may begin to emerge when infants first speak and understand natural language expressions that both refer to objects and convey social intentions. Although infants as young as 6 months interpret some words as referring to social events ("bye bye!"), to people ("mama," "Simon") and to objects ("apple," "feet"), only at the end of the first year do infants appear to understand expressions that combine these words ("Look, Simon, an apple!"). Infants' new understanding of people as social agents might depend, in part, on their emerging ability to interpret such expressions: Social agent concepts may become available as infants begin to master words and expressions that convey a speaker's social goals. With these concepts, infants can view the communicative actions of speakers as both directed to people and referring to objects.

With a concept of social agents, young children may begin to make sense of actions and relationships that are both instrumental and social, such as cooperating, teaching, and helping. They also may begin to conceive of mental states as both intentional relations to objects and as shareable phenomenal experiences. Thus, children can begin to learn what actions are helpful in a given social context and what mental states are likely to guide a particular social action—two prerequisites for moral reasoning. Like the development of knowledge of number and geometry, this learning proceeds slowly; it takes children many years to sort out, for example, the specific mental states that are most likely to guide a social agent's actions in a given situation. Over time, however, children will develop a consistent and workable system of knowledge that is unique to our species.

To my knowledge, little evidence bears on this hypothesis, but it makes testable predictions. In particular, natural variation in the pacing of language development should predict variation in the onset of uniquely human forms of communication, cooperation, mental state reasoning, and moral evaluation; diminished access to a natural language should delay these developments; and language training should accelerate them. Except in the case of mental-state reasoning (e.g., Milligan, Astington, & Dack, 2007), these predictions are largely untested.

If any version of the combinatorial capacity hypothesis is correct, then our uniquely human social cognitive capacities are a consequence, rather than a cause, of the fundamental capacity that distinguishes us from other animals. In the domain of social cognition, as in the domains of number and geometry, children may come to combine representations from different core domains to create new concepts and systems of knowledge. If they do, then the key features of human cognition that distinguish us from other animals would not be our distinctively social talents but our pervasive and unstoppable penchant for forming new and more powerful concepts in any domain (Carey, 1985, 2009). The domain of social cognition may be an especially informative one in which to test this hypothesis, because it likely is the first domain in which humans move beyond core concepts and construct a new and uniquely human system of knowledge.

ACKNOWLEDGMENTS

Warmest thanks go to Shari Liu, Alia Martin, and two anonymous reviewers for comments and suggestions on an earlier version of this chapter. The chapter is based on work supported by a grant from the National Institutes of Health (NIH) (HD23013) and by the Center for Brains, Minds and Machines (CBMM), funded by National Science Foundation (NSF) STC award CCF-1231216.

NOTE

1. Carey (2009) has made a strong case that the development of the natural number system depends on mastery of counting, as well as on reasoning processes of the sort that underlie conceptual change in formal science education and in the history of science. I disagree: Our use of the natural number system is greatly aided by mastery of culture-specific devices such as a counting

procedure, a conventional base system, and Arabic notation, but the construction of natural number concepts does not depend on those devices (see Izard et al., 2014, for relevant evidence). Behind this specific disagreement is a more general question concerning the role of cultural evolution and historical change in human cognitive development. I do not pursue this question here.

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