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Development of Thinking in Children

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Abstract

Children's thinking is of broad relevance to the study of thinking and reasoning, because it provides insight into fundamental issues concerning the building blocks of cognition, the role of experience, and how conceptual change comes about. The present chapter reviews four main aspects of children's thinking: *(1)* developmental changes, and how best to characterize such changes; *(2)* early cognitive capacities in infancy and early childhood, and the methodological tools that reveal these capacities; *(3)* causal reasoning and naive theories in childhood; and *(4)* the ways in which children are prepared to learn from the actions and testimony of others. The chapter ends with open questions and directions for future research.

Key Words: children, thinking, causal reasoning, naive theories, testimony, development, Piaget

Introduction

Why Study Thinking in Children?

Many people study thinking in children because they are interested in children: They may work with children in some capacity (as a teacher, or a speech therapist, for example), or they are parents and have had opportunity to observe their own child's growth (as with Charles Darwin, who wrote detailed observations of the development of his oldest son, William), or they may simply find children to be charming and inherently interesting (recall the popularity of the television show *Kids Say the Darndest Things* in the 1990s). There are also several theoretical reasons that the study of children's thought is relevant, indeed central, to anyone interested in thinking and reasoning.

(1) *The study of children tells us how knowledge comes about and how it evolves.* The kinds of learning that take place in childhood are profound. Consider that in the first 4 years of life, children construct mental structures to deal with number, space, time, human relationships, physical principles, and organization of the objects and events surrounding them. These achievements entail inherently developmental issues—conceptual change, critical periods, nature-nurture—that can best be studied by a focus on children.

(2) *A focus on children reveals what is intelligent in even the humblest of behaviors.* The simple act of grasping a rattle, or sucking on a hand, or retrieving a dropped toy, can reveal layers of capacity and skill (Oztop, Bradley, & Arbib, 2004; von Hofsten, 2007). This, in turn, helps sharpen the questions, What is thinking? and What are its separable components?

(3) *A focus on children tells us about human preparedness.* What is special about our species that permits us to learn certain skills rapidly and with minimal training? Language is a key example. Children are actually better language learners than adults (Johnson & Newport, 1989).

This suggests a biological preparedness to learn language. At the same time, this prepared learning takes place within certain constrained conditions (e.g., learning from live interlocutors, not televised images; Kuhl, Tsoa, & Liu, 2003).

(4) *Childhood lays bare human reasoning biases.* Human thought is limited, biased, and prone to heuristics and shortcuts (Gigerenzer, 2000; Kahneman, Slovic, & Tversky, 1982). If one focuses on adults, these limitations can sometimes be difficult to see. In children, however, they are overt. One example is that of egocentrism. Originally proposed by Piaget and Inhelder (1956) to be characteristic of an early developmental stage, it turns out to be a tendency throughout the lifetime (Keysar, 2007).

(5) *Development is a methodological tool.* The study of development answers questions that cannot otherwise be addressed when reasoning structures are well in place. Stephen Jay Gould (1983) exemplifies this point in his discussion of whether a zebra is a white animal with black stripes or a black animal with white stripes. An examination of a mature zebra provides no insight, since white and black stripes are intertwined. To answer this question, biologists have had to examine the developing zebra embryo (thereby reaching the conclusion that a zebra is a black animal with white stripes!). When focusing on human thought, developmental methods likewise permit special insights: Longitudinal methods reveal the stability of traits or beliefs over time, and microgenetic methods reveal the process of change as it unfolds (Siegler & Crowley, 1991).

Plan of This Chapter

This chapter takes a selective approach to the vast subject of the development of thinking, focusing on four main topics. First, we review the broad developmental changes in thought that take place in childhood, and we briefly discuss theoretical debates concerning how best to characterize these changes. Second, we review a sampling of the rich and varied evidence for early cognitive capacities, in infancy and early childhood. A consistent theme throughout the past 40 years has been the surprising complexity and sophistication of early thought. In this section, we also briefly touch on the importance of appropriate methodological tools for uncovering these abilities. Third, we consider the realm of causal reasoning and naive theories, as an example of the cognitive structures that children are building as well as processes that contribute to those structures. Finally, we note the importance of social input to children's developing thought, and the ways in which children are prepared to learn from the actions and testimony of others.

Developmental Change

When interacting with children, one is immediately struck by the differences in behavior as a function of age. Just by knowing a child's age, it is possible to predict quite accurately which skills the child will and will not yet have acquired. A newborn infant can't grasp a toy or recognize herself in a mirror, let alone talk or add a series of numbers. A 5-year-old child is highly skilled at language and mirror recognition and can recall past events but typically can't yet read or multiply numbers. A 10-year-old child can read, write, multiply, and divide but doesn't seem to have much grasp of the political issues of the day, has no methodological approach to scientific problems, and reasons about moral issues in a manner that seems rather rule-bound and rigid. A 17-year-old seems on a different plane of thought, able to reason skillfully about all of the issues that elude the younger children.

The theory that is best known and most influential to describe and explain these developments is that of Jean Piaget, the prominent Swiss scholar who is widely considered the "father" of cognitive developmental psychology. Piaget is rightly credited for a number of remarkable achievements. He came up with an ambitious, overarching theory that explains all of cognitive development (as opposed to working on just one aspect or sliver of cognition), and he is still recognized as capturing fundamental differences between children of different ages. Aspects of his theory are surprisingly forward looking and validated by more recent research. Piaget envisioned children as active, constructive thinkers, not simply passively taking in information supplied by others. He emphasized the importance of intrinsic motivation (vs. reward). And, over the course of a remarkably productive career, he made an amazing variety of interesting observations about children's thinking across many topics ranging from children's understanding of physical causality to their understanding of dreams, to their understanding of morality.

It is beyond the scope of this chapter to provide a full description or evaluation of Piaget's theory (see Flavell, 1963; Ginsburg & Opper, 1969; Piaget, 2000). However, we will briefly review his theory of stages and turn to four broader questions that underlie this framework: whether there can be said to be qualitative change over childhood in the nature of thought; whether children's thinking is domain general or domain specific; the nature of individual and cultural variation; and the effects of training and environmental experiences on cognitive development.

Piagetian Stages: A Brief Overview

Piaget proposed that children progress through four stages of thought, corresponding to distinct age periods: sensorimotor (0–2 years), preoperational (2–7 years), concrete operational (7–11 years), and formal operational (11 years +). Each of these stages is said to be characterized by certain limitations as well as certain achievements. For example, at the beginning of the sensorimotor period, infants don't realize that objects still exist when they disappear from view (i.e., they lack object permanence); at the beginning of the preoperational period, children don't realize that quantities are unchanging if their shape is transformed (i.e., they lack conservation of number, conservation of volume, etc.).

According to Piaget, stages have the following characteristics: Each stage is a qualitative advance from the previous stage; at a given stage, thinking is uniform, making use of the same structures to address a broad range of problems across a broad range of topics; the sequence of stages is unchanging and universal; and children can't be trained to move to a new stage before they're ready. Each of these assumptions has been called into question on the basis of more recent research evidence, which we review here.

Qualitative Versus Incremental Change

One tenet of stage theories is that children undergo qualitative changes in thought over time. For example, Piaget and Inhelder (1956) proposed that preoperational children are egocentric, literally having difficulty taking into account a perspective other than their own. On this view, it is not until the concrete operational stage that nonegocentric thought becomes possible. For example, when given a three-dimensional display depicting three mountains and asked to report the perspective of a person sitting across the table from themselves, preschool children typically report that the person sitting across from them will see the same spatial perspective as their own. In contrast, by 7 years of age, children will consistently report the other person's perspective correctly.

One of the central challenges to a stage theory is that Piaget underestimated children's abilities—sometimes strikingly so. Although there is controversy regarding just how capable infants and young children are (see Woodward & Needham, 2009, for discussion), there is broad agreement than children are much more capable than Piaget's initial observations would suggest (see the later section entitled "Early Competence"). This critique has been directed toward both methodological and theoretical issues. At a methodological level, the concerns are multiple. Piaget's methods were highly demanding and complex from an information-processing perspective. Children were often asked to explain their answers (thus requiring verbal and metacognitive abilities, in addition to whatever conceptual capacity was being measured). In addition, Piaget's tasks were often embedded in an unfamiliar experimental context that did not permit children to make use of more familiar strategies or contexts. (We also note, however, that novel contexts may be required to reveal reasoning as opposed to retrieval of learned routines.)

Considering once again the example of egocentrism, researchers have found that a variety of modifications can lead to significantly earlier success on a perspective-taking task, including the following: simplifying the display (e.g., presenting a single object with distinctive vantage points, such as a mouse holding a candle in one hand, rather than a scene with multiple objects; Fishbein, Lewis, & Keiffer, 1972), simplifying the task (e.g., asking the child to rotate the mouse so that the candle is facing the researcher, rather than reporting a given perspective; Fishbein et al., 1972), or embedding the task in a more natural set of actions (e.g., communicating the presence of a hidden toy to a parent who has either witnessed the hiding event or not; O'Neill, 1996).

Furthermore, careful task analysis reveals that constructs that Piaget analyzed as unitary may have different levels, so that early capacities are present much younger than Piaget would have granted (again, undermining the notion of a qualitative leap in capacity). For example, perspective-taking turns out to have at least two distinct levels that emerge at different points developmentally (Flavell, Everett, Croft, & Flavell, 1981). Level-1 perspective taking entails knowing *that* someone has a different perspective from one's own; Level-2 perspective taking entails knowing *what* that perspective is. Children may fail to figure out what perspective another person has, while still having a basically nonegocentric grasp of perspectives. Furthermore, children

18 months of age understand that different people can have competing desires (Repacholi & Gopnik, 1997), even though an understanding of competing beliefs takes longer to develop (Bartsch & Wellman, 1995; Rakoczy, Warneken, & Tomasello, 2007).

From a theoretical standpoint, researchers have criticized Piaget's assumption of developmental "dichotomies" (e.g., from concrete to abstract; Keil, Smith, Simons, & Levin, 1998). They note that the reverse developmental pattern can take place as well: An abstract conceptual "framework" may then later be filled in with specifics. For example, long before children have learned the particulars of what differentiates the insides of animals versus machines, they expect animals and machines to differ in their internal parts (Simons & Keil, 1995).

A final point of criticism is that adult thinking isn't as logical and mature as Piaget had suggested. Egocentrism provides a compelling example. Rather than being restricted to a particular developmental stage, egocentrism is found even among adults, using more subtle methods. For example, when placed in a referential communication task and given an ambiguous instruction that could be interpreted from either the speaker's perspective or from an egocentric perspective, adults first gaze toward the referent that is the egocentric interpretation (Keysar, Barr, Balin, & Brauner, 2000). Similarly, when asked to judge whether a hypothetical hiker would be in greater need of food or drink, participants implicitly take an egocentric perspective, being more likely to select "drink" when they themselves are thirsty than when they are not (Van Boven & Loewenstein, 2003).

What do these critiques of Piaget imply about the broader issue of qualitative versus incremental change? Some have concluded that there is no qualitative change in cognitive development, and that instead what is most striking is the continuity from childhood through adulthood (Keil, 1981; Spelke, 2004). Others argue for qualitative change, without the additional commitment to stages, though the nature of that change is quite varied. For example, some have proposed that children's thought changes from associative to theory based (Rakison & Lupyan, 2008; Sloutsky, 2003), whereas others argue that children's thought is more akin to theory change in science (Carey, 2009; Gopnik & Schulz, 2004). Maturational changes (e.g., in working memory; in prefrontal cortex and inhibitory control) have also been proposed to yield stage-like shifts (Case, 1992, 1995; Halford, Cowan, & Andrews, 2007; Morrison & Knowlton, Chapter 6). These issues are among the most central puzzles of cognitive development.

Domain Generality Versus Domain Specificity

Piaget proposed that thinking at a given stage was "all of a piece"—a child who is preoperational when reasoning about quantity is also preoperational when reasoning about morality, gender, classification, or perspective taking. In other words, he assumed that *domain-general* principles characterize thought. Although domain-general principles are important, more recent evidence shows that domain-specific principles are also important. For example, children do better than adults at learning a second language, whereas adults do better than children at learning higher mathematics, thus suggesting that different processes are at work in these different domains (Gelman & Noles, 2011).

At least three sources have been offered to account for domain differences in cognitive development: modularity, experience and expertise, and causal theories. Modularity is the position that certain cognitive processes are biologically constrained as the result of our evolutionary heritage. Development in these areas is thought to be highly predictable, making use of innate structures and domain-specific processes. Often (though not necessarily) these domains are associated with particular brain regions. A classic example is that of face perception, which emerges early and predictably in infancy and is associated with the fusiform face area (FFA) in the brain (Kanwisher & Yovel, 2009). Other cognitive processes that have been hypothesized to reflect modularity are language acquisition (Pinker, 1994) or numerical reasoning (Feigenson, Dehaene, & Spelke, 2004).

Expertise can also exert powerful domain-specific effects in children's cognitive performance. A striking example is that a child chess expert outperforms an adult chess novice, when it comes to memory for chess pieces on a chessboard (Chi, 1978). These differences disappear when examining memory outside the domain of expertise (e.g., digit span). One area where expertise effects have significant long-term implications is that of becoming a skilled reader, and there is great interest in understanding the changes that take place with increasing literacy experiences (Treiman & Kessler, 2007).

A final perspective on domain specificity is that children construct causal knowledge structures, often referred to as naïve theories, that reflect the particular ontology and causal processes of a particular domain (e.g., a theory of mind concerns thoughts and beliefs; a theory of physics concerns objects and forces). On this view, children are seen as analogous to scientists who devise theories to explain phenomena around them and revise those theories in light of contradictory evidence. However, young children differ from scientists in several important respects: They do not systematically test the hypotheses they entertain, and they do not engage in precise measurement or disconfirmation of alternative hypotheses (Kuhn et al., 1988). Nonetheless, children are like scientists in positing basic ontological distinctions and making causal predictions (Wellman & Gelman, 1998). Furthermore, children take in new evidence and revise their hypotheses on the basis of such evidence, as can be seen in the layers of increasing detail and specificity in infants' understanding of physical support (Baillargeon, Li, Ng, & Yuan, 2009).

Individual and Cultural Variation

One area that has not received much research attention concerns the nature of individual differences in cognitive development, as well as cultural variation in the processes of developmental change. Of particular interest is whether these simply involve changes in *rate* of development (e.g., some individuals achieving a certain milestone earlier than others), or whether there are qualitative changes in the *process or outcome* of development.

Recent evidence suggests that there are remarkably stable individual differences in various areas, including theory-of-mind reasoning (Wellman, Lopez-Duran, LaBounty, & Hamilton, 2008), mathematics reasoning (Halberda, Mazzocco, & Feigenson, 2008; see Opfer & Siegler, Chapter 30), and processing speed (Rose, Feldman, & Wallace, 1988). For example, individual differences at age 14 in children's ability to discriminate large, uncountable sets of dots in a visual attention task correlate highly with scores on standardized mathematics achievement tests going back to kindergarten (Halberda et al., 2008). These data suggest that differences found in infancy or early childhood relate to more complex tasks presented later in life, and they argue for continuity across strikingly different tasks.

The importance of cultural context is also a critical issue that has not been sufficiently acknowledged in the past but is beginning to receive more attention. Research with adults demonstrates that cognitive principles once thought to be universal may reflect particular cultural values (Markus & Kitayama, 1991; Nisbett, 2003). For excellent developmental work on this topic, see Greenfield, Keller, Fuligni, and Maynard (2003), Rogoff (2003), Astuti, Solomon, and Carey (2004), and Waxman, Medin, and Ross (2007).

Effects of Training and Experience

Piaget (1964) famously proposed that training cannot affect the progression of stages; the child must be developmentally ready before he or she is capable of benefitting from experience. To some extent this is certainly true: A lesson in calculus will have no effect on a 4-year-old child. Yet it is also clear that children are much more susceptible to training effects than Piaget had originally conceived. Recent intriguing studies demonstrate that certain motor experiences have broad cognitive consequences. For example, the onset of self-propelled locomotion (either crawling or use of a walker) is associated with a host of changes, including reluctance to cross a visual cliff (Campos et al., 2000). Furthermore, providing 3-month-olds with the means to pick up objects, by giving them "sticky mittens" (i.e., Velcro-backed mittens and Velcro-backed toys), leads them not only to explore the objects more intensely (Needham, Barrett, & Peterman, 2002) but also to interpret perceived events in a more sophisticated way (i.e., seeing a reach toward an object as directed toward a particular goal, rather than just a movement of a certain trajectory; Sommerville, Woodward, & Needham, 2005).

Experience can also lead to dramatic changes in perceptual and categorical processing. For example, specific experiences can lead to a process known as perceptual narrowing. At 6 months, infants can universally discriminate all the phonemes of the world's languages (e.g., p vs. p; l vs. r). However, with experience with just their native tongue(s), by 12 months infants lose the capacity to distinguish phonemes to which they are not exposed (e.g., infants exposed to just Japanese lose the capacity to distinguish l vs. r; infants exposed to just English lose the capacity to distinguish two different t sounds in Hindi; Werker & Desjardins, 1995). Perceptual narrowing is not simply an effect of speech perception, but rather seems to be found in a broad range of perceptual abilities (Scott, Pascalis, & Nelson, 2007). One intriguing example concerns face perception, where infants at 3 months show the capacity to discriminate faces of all races equally well, but by 9 months do much better discriminating faces to which they have been exposed; for example, White babies distinguish other White faces better than Asian faces (Kelly et al., 2007).

Early Capacities

In the prior section, we reviewed some of the evidence indicating that children are much more capable than traditional Piagetian theory would suggest. In this section we consider what children's early capacities are like. We start by discussing methodological issues. Then, because this topic is too large to review in entirety, we have selected a few key themes: infants can represent objects and events; children are not limited to concrete representations; and learning concepts entails more than forming associations. Collectively, these phenomena illustrate the surprising subtlety and sophistication of early thought.

Methodology Matters

One firmly established lesson from the past 40 years of research on children's cognitive development is that methodology matters: How one operationalizes and assesses children's thinking has a powerful influence on children's performance and on the conclusions we draw about their capacities. Time and again we see that task modifications can lead to much more sophisticated performance. Children—especially young children—face difficulty when presented with tasks that require sophisticated verbal, metacognitive, planning, or information-processing skills. For example, Piaget's object permanence task requires that infants pull a cover off a hidden object to demonstrate knowledge that an object remains in existence even if it is out of sight. This requires an ability to hold and grasp the cover, as well as sufficient memory and planning skills to keep in mind the goal of retrieving the object while focusing on the task of removing the cover. The method of tracking infants' looking-time presents a much less demanding task (all babies need do is look), and it shows that infants do indeed track the existence of hidden objects, expecting them to occupy space of a certain size (and therefore evidencing surprise when a barrier moves through the space that the object should occupy; Baillargeon, 1987). More generally, numerous experimental techniques have been devised for infants that make use of the behaviors they have at their disposal (e.g., habituation, head turning, or high-amplitude sucking techniques; Cohen & Cashon, 2006).

Moreover, in some cases infants have limitations that interfere with a conceptual understanding they in fact possess. A good example of this is again with object permanence tasks. One clever task that Piaget devised is the "A-not-B" task, where babies see a desired object hidden repeatedly at one location (A), and then see the object hidden at a new location (B). By 10 months of age, infants successfully find the object in location A, but erroneously continue to search at location A even when they saw the desired object being hidden at B. This is known as the A-not-B error. Piaget attributed this error to an incomplete representation of the object. However, it turns out that a difficulty inhibiting well-practiced responses contributes to this error (Diamond, 1991).

Even when studying older children, it is easy to underestimate their capacity. One problem is that children have difficulty verbalizing concepts that they possess. For example, children have trouble talking about traits (Livesley & Bromley, 1973), yet they show an understanding of cross-situation consistency when tested with more directed questioning (Heyman & Gelman, 1998; Liu, Gelman, & Wellman, 2007). Another issue involves information-processing demands. For example, one study found that children's pattern of picture recall seemed to differ systematically from that of adults, with children focusing exclusively on individual items and adults focusing exclusively on the category to which the items belonged (Sloutsky & Fisher, 2004a, b). However, when the length of time each item was presented to participants is controlled, by equating the length of exposure for children and adults, the developmental difference disappeared (Wilburn & Feeney, 2008).

Although simpler methods reveal earlier capacities in children, this point does not imply that there are no developmental changes in children's cognitive abilities. At times, simplified tasks reduce the need for sophisticated performance. Similarly, earlier knowledge can be more fragile or limited than later understandings. Thus, for example, although even preschool children can perform analogical reasoning when the perceptual or causal bases for comparisons are made salient (Goswami, 1992), there are nonetheless developmental changes in the depth, complexity, and sophistication of the conceptual relations children can consider (Uttal, Gentner, Liu, & Lewis, 2008).

Infants Can Represent Objects and Events

As seen by the earlier brief review of object permanence, we now know that preverbal infants can represent objects and events, even when they are out of sight. Not only do infants represent that an object exists, they also represent details of that object, such as its height, density, solidity (e.g., object vs. substance), and capacity to contain things (Baillargeon et al., 2009). They can link visual cues with cross-modal cues (e.g., understanding that a visually bumpy surface matches a tactilely bumpy surface; Gottfried, Rose, & Bridger, 1977). They expect objects to display unity across time and space (Spelke, 2004). They represent the distinction between animate and inanimate objects and expect only animate objects to move on their own (Opfer & Gelman, 2010). They can interpret point-light displays and distinguish animate from inanimate motion on this basis (Arterberry & Bornstein, 2002). They detect patterns in complex motion, parsing action into distinct events (Baldwin, Baird, Saylor, & Clark, 2001). And they represent the number of objects in an array and can perform simple operations of addition and subtraction (Wynn, 1992).

Preverbal infants are also capable of representing information over time; that is, they form enduring memories. Thus, upon viewing a novel event, such as a person making a special lightbox light up by pushing down on it with his forehead, 9-month-olds remember the event over a delay, reproducing the event when presented with the box 1 week later (Meltzoff, 1988). Infants can remember novel events (e.g., the steps required to form a toy rattle) over periods lasting a year or more, although the quality of the memory and the amount retained over time improve with age (Bauer, 2006).

Infants still have a tremendous amount to learn about the world around them, but they have a wealth of early-emerging capacities that make sense of experience.

Young Children Are Not Limited to Concrete Representations

A long-standing and persistent view in the developmental literature is that development entails a process of moving from concrete to abstract. On this view, young children are capable of holding only *concrete* representations and are unable to form more abstract ideas (see Simons & Keil, 1995, for review). This position, however, is belied by a variety of evidence showing that even preschool children readily reason about nonobvious, nonvisible, or abstract entities. One realm in which this is powerfully demonstrated is that of reasoning about mental states (thoughts, beliefs, desires). Although there is clear improvement over time in children's theory of mind (Wellman, in press; Wellman & Liu, 2004), even before 2 years of age, infants implicitly recognize that a person may hold a false belief (Onishi & Baillargeon, 2005), and that a failed action nonetheless has an intended goal (Brandone & Wellman, 2009; Meltzoff, 1995).

Another demonstration of children's ability to represent abstraction is in the realm of what is called "generic knowledge" (Prasada, 2000). Although children have experience strictly with individuals (this apple, that chair), they rapidly and readily generalize from experience with individuals to abstractions regarding the category as a whole (apples, chairs; Waxman & Markow, 1995). For example, by 30 months of age, children make use of subtle linguistic cues ("Blicks drink milk" vs. "These blicks drink milk") to extend a novel property to a broad class of instances (Graham, Nayer, & Gelman, 2011). Generic concepts may even be a default representation for young children, as they seem to learn generics before more formal modes of expressing generalization such as quantified noun phrases (e.g., "all blicks;" Hollander, Gelman, & Star, 2002; Leslie, 2008).

By 3 years of age, children can use verbal information to update their representations of absent objects (Ganea, Shutts, Spelke, & DeLoache, 2007) and use abstract symbols such as maps or model representations to skillfully to navigate through space (DeLoache, 1987; Uttal, Gregg, Tan, Chamberlin, & Sines, 2001). They can reason about abstract relations, such as ownership, despite the fact that an owned object is concretely no different from a nonowned object (Blake & Harris, 2009; Gelman, Manczak, & Noles, in press; Kim & Kalish, 2009; Neary, Friedman, & Burnstein, 2009; Williamson, Jaswal, & Meltzoff, 2010). For example, they place special value on their own special toys or objects and would much rather own the original attachment object than an exact duplicate (Hood & Bloom, 2008). They believe that food or drink can contain invisible particles (Au, Sidle, & Rollins, 1993; Legare, Wellman, & Gelman, 2009), and that germs can lead to illness (Kalish, 1996; Raman, 2009). They believe that unseen internal parts or power can have causal effects (Gelman, 2003; Gottfried & Gelman, 2005; Sobel, Yoachim, Gopnik, Meltzoff, & Blumenthal, 2007). They seem to posit an invisible "essence" shared by members of a category (Gelman, 2003).

The evidence indicates that children are not limited to concrete representations. Indeed, in some cases the developmental process is from abstract to concrete rather than the reverse: The child at times starts with a more abstract representation that then gets filled in with concrete details over time (Gelman & Williams, 1998; Simons & Keil, 1995; Wellman & Gelman, 1998).

Learning Concepts Entails More Than Forming Associations

Another important theme regarding cognitive development is that when children learn concepts (and words to express those concepts), they are not simply forming associations but instead are creating meaningful interpretations of experience (Waxman & Gelman, 2009). For example, Preissler and Carey (2004) taught 18-month-old and 24-month-old toddlers a new word ("whisk") while showing them a photograph of the referent (namely, a photo of a whisk). After repeated experience with this name-picture association, children were presented with a test in which they were asked to pick the "whisk," given a choice between *(1)* another photo that was highly similar to the one used during teaching and *(2)* an actual, three-dimensional whisk object. If the word-learning process is merely one of association (see e.g., Sloutsky, 2003), then children should select the choice that is more perceptually similar to the taught-upon item, namely, the picture. However, if the word-learning process entails conceptual interpretation, then children should understand the relationship to involve *reference* (not merely association) and select the object (which the picture symbolizes). When this same experiment is conducted with autistic children, they respond differently, linking the word with the picture—thus arguably treating the word as associatively linked to the object rather than representing the object (Preissler & Carey, 2005).

A further important demonstration that children do not treat word-object links as purely associative is that children attend to pragmatic, communicative cues from the speaker. If such cues are unavailable, children will not link a word to a referent. Thus, if a novel word is presented in an incidental, nonintentional manner (e.g., projected over a loudspeaker in the room in which the child is sitting), children fail to link the word to the object. The word must be spoken in an intentional, face-to-face interaction (Baldwin, 1993). Furthermore, if the speaker and the child are initially focused on different objects, children check the speaker to gauge her direction of gaze and link the word to the speaker's focus of attention, not to their own initial focus of attention (Baldwin, 1993). Put a slightly different way, the association between word and object is blocked when the appropriate communicative cues are not in place. Again, however, autistic children perform differently, linking the word to their own focus of attention rather than that of the speaker (Baron-Cohen, Baldwin, & Crowson, 1997). Finally, if the speaker expresses some uncertainty as to the correctness of the label, children also fail to link the word to the referent (Sabbagh & Baldwin, 2001). Again, this suggests that the word-object relationship is one of reference rather than association.

Causal Reasoning and Naive Theories

A number of researchers have advanced the view that children's thought can be construed as sharing important similarities with scientific theories, with a focus on domain-specific ontologies, causal processes, and coherent knowledge structures that undergo qualitative reorganizations over time (Carey, 1985; Gopnik & Wellman, 1994). Although the analogy is imperfect (e.g., young children are poor at conducting systematic scientific investigations to test their theories; Kuhn et al., 1988), the "theory theory" has been a productive framework for characterizing cognitive development. In this section, we focus on the role of ontologies and causation in children's early reasoning, as well as the implications of the theory theory for conceptual change.

Ontologies

Ontological commitments are those that distinguish different kinds of entities that participate in distinct causal laws. For example, everyday intuition tells us that mental states are distinct from physical objects, even though the mind influences the body (and vice versa), and even though mental states ultimately have a physical basis in the brain. Despite these demonstrable links between mental and physical, we act as if mental entities and physical entities are wholly different sorts of things. Indeed, children and adults alike seem to have difficulty even considering a relation between these two domains, maintaining a strict dualism (Bloom, 2004; Notaro, Gelman, & Zimmerman, 2001; Schulz, Bonawitz, & Griffiths, 2007).

From early childhood, children show evidence for ontological commitments in at least three distinct domains: physics, psychology, and biology (Wellman & Gelman, 1998). That is, they have expectations regarding three-dimensional, bounded physical objects, expectations regarding mental states and mental activities, and expectations regarding self-moving, spontaneously growing entities. Thus, even infants expect that objects, but not shadows, occupy space (Van de Walle, Rubenstein, & Spelke, 1998), that mental states are distinct from physical objects (Wellman, in press), and that people and inanimate objects engage in different patterns of object motion (Opfer & Gelman, 2010).

Causality

Infants are also highly sensitive to causal relations linking objects or events. For example, 3-month-old infants readily learn the contingency between their own action and a causal effect (e.g., kicking to make a mobile move; Rovee-Collier & Barr, 2001), and within the first year of life, infants respond with more positive affect to events that they cause versus those that are uncorrelated with their actions (Gunnar-Vongnechten, 1978; Lewis, Alessandri, & Sullivan, 1990; Watson, 1972). Seven-month-old infants also distinguish a causal physical event (e.g., a ball colliding with another ball, causing it to move) from the backward version of that same event (Leslie, 1984; but see Oakes & Cohen, 1990).

An attention to causal relations can be seen in older children's commonsense theories as well. Children place special priority on causal features, treating them as more important than other sorts of features (an effect known as the "causal status hypothesis"; Ahn & Kim, 2001). For example, if children learn that a novel animal has three features, one of which (promicin in its bones) causes the other two (thick bones, big eyes), they are more likely to classify a new instance as a member of that category if it possesses the causal feature but is missing one of the other two features, than if it possesses the other two features but is missing the causal one (Ahn, Gelman, Amsterlaw, Hohenstein, & Kalish, 2000).

Within specific theories, children display a combination of openness to new causal relations (informed by statistical patterns in the input) and expectations or biases that are informed by prior knowledge and/or ontologies. So, for example, children are highly attentive to statistical cues in the input and use them to learn about how a machine works (Gopnik & Sobel, 2000), what a new word means (Xu & Tenenbaum, 2007), or how to generalize a new property from one animal to another (Rhodes, Gelman, & Brickman, 2010). At the same time, children have a "self-agency bias," whereby they are biased interpreters of statistical evidence: They are more likely to interpret their own action as having a causal effect than the actions of another person (Kushnir, Wellman, & Gelman, 2009).

As another example, children below about 10 years of age expect that mental states cannot have physical effects, thereby resisting the notion of psychogenic illness (e.g., worrying causing a stomach ache; Schulz et al., 2007). However, if children receive repeated empirical evidence in favor of such a causal account, then even 3-1/2-year-olds can overturn this assumption (Bonawitz, Fischer, & Schulz, in press). Children, like scientists, make use of a combination of preexisting theoretical assumptions and empirical evidence to derive new conclusions (see Cheng & Buehner, Chapter 12).

Theory Change

One of the more far-reaching implications of treating children's concepts as organized into naive theories is what this approach suggests about conceptual change. Carey (2009, p. 18) argued that theory change in childhood is analogous to theory change in science: "human beings, alone among animals, have the capacity to create representational systems that transcend sensory representations and core cognition... [they] create new representational resources that are qualitatively different from the representations they are built from." For example, although infants have an innate capacity to represent quantities (a parallel individuation system that represents individuals and so permits solving simple addition and subtraction problems; Wynn, 1992), they do not accurately represent positive integers until 3 or 4 years of age (Carey, 2009). Other domains in which conceptual change has been argued for and studied include object kinds, social kinds, theory of mind, matter/substance, and heat/temperature.

Learning From Others

To this point, we have largely focused on the impressive capacities and knowledge of infants and children. However, cognitive development happens not just in the head of the developing individual but also through a process of social interactions with others from whom children can learn (without having to discover everything themselves; see Gelman, 2009, Rogoff, 2003; Vygotsky, 1934/1962).

Learning from others is a powerful tool for gaining knowledge about a range of topics, and especially those that are difficult to observe firsthand (Harris & Koenig, 2006). For example, during the preschool and elementary school years, children learn about how our brains are related to thinking, remembering, and personal identity (Johnson

& Wellman, 1982); they learn that the earth that we live on is a sphere despite the flat appearance of the surrounding ground (Vosniadou & Brewer, 1992); and they learn that when a living thing dies, it is often related to the breakdown or cessation of hidden internal body parts (such as a heart that stops beating; Slaughter & Lyons, 2003). Coming to these conclusions would be difficult without the provision of information (or "testimony") from more expert adults (Harris & Koenig, 2006).

Pedagogical Stance

From infancy onward, children seem to expect that the people around them have the goal of teaching them new information (i.e., a "pedagogical" stance; Csibra & Gergely, 2009). Infants and young children interpret and learn differently from situations that they construe as pedagogical (e.g., where the adult deliberately seeks and maintains eye contact with the child) than from situations that they construe as nonpedagogical (e.g., where the adult makes no attempt to engage the child's attention). They seem biased to interpret intentional communication as conveying information that will generalize to new contexts. For example, to use Csibra and Gergely's example, if I demonstrate how to open a certain type of container (e.g., a milk carton), the child will assume that I am teaching him how to open containers of that kind in general. He does not need repeated demonstrations in order to reach this conclusion. Furthermore, some of children's seeming "errors" can be reinterpreted in light of this bias. For example, consider infants' classic A-not-B error (searching for an object in a location where it has most typically been hidden, rather than in the location where it was last hidden; Piaget, 1954). Csibra and Gergely suggest that this error reflects infants' assumption that the adult is teaching them where the toy is supposed to be stored (i.e., they assume that the adult is teaching them something general about this toy). And indeed, consistent with this interpretation, if the experimenter does not provide communicative cues (e.g., by not first making eye contact with the infant), then the A-not-B error is greatly reduced (Topál, Gergely, Miklósi, Erdőhegyi, & Csibra, 2008).

Imitation

One important means of obtaining information from others is imitation, or copying the actions of others. It is well established that children can engage in imitation of others from earliest infancy (Meltzoff & Moore, 1977; Meltzoff & Williamson, 2010). Furthermore, children's imitation appears to have certain qualities that are distinct from that of other species. First, children imitate rather than merely emulate (Tomasello, 1999). That is, children attempt to copy the model's (intentional) actions, and they do not simply learn something about the environment as a result of observing the results of the model's actions. For example, if shown how to obtain a toy by holding a tool in a particular fashion, young children will carefully rotate the tool to imitate the precise action of the model, whereas apes will not attend to the manner in which the tool is used (Penn & Povinelli, Chapter 27; but see Whiten, McGuigan, Marshall-Pescini, & Hopper, 2009, for some evidence of imitation in chimpanzees).

Second, children overimitate rather than just focus on the relevant task dimensions (Lyons, Young, & Keil, 2007). For example, if shown how to operate a novel machine using a sequence of actions that includes both causally efficacious (e.g., removing a bolt) and causally irrelevant steps (e.g., tapping on an empty compartment), preschool children will imitate both the efficacious and irrelevant steps. Lyons et al. suggest that children do so because they presume that all the steps provided by the model are causally relevant, even in the face of seemingly contradictory evidence.

And third, children imitate intentional actions and intended actions, rather than just surface behaviors (Meltzoff, 1995). Thus, if 18-month-old children view an adult engaging in an unsuccessful attempt to extract a toy from a location, but where the intended goal is clear, they will imitate in such a way as to carry out the intended action, and not simply to carry out the observed (uncompleted) motor movements. Thus, children's imitation does not simply involve mimicking surface features of an action, but it entails consideration of the model's intentions. If an action is highlighted as clearly accidental rather than intentional, toddlers will selectively imitate the intentional aspect (Carpenter, Akhtar, & Tomasello, 1998). Similarly, if an unusual action (e.g., turning on a lightbox with one's head rather than one's hands) has no obvious causal basis, children imitate precisely what the model has done (turning it on with their head), but if the unusual action has an obvious causal basis (e.g., the model's hands are otherwise occupied), then children imitate the more efficient means of carrying out the result (e.g., turning it on with their hands) (Gergely, Bekkering, & Király, 2002).

Evaluating Testimony

Although children learn in contexts that are intended to be instructional, they also extract a great deal of knowledge from the everyday activities taking place around them (Callanan, 2006). For example, everyday conversations provide a rich source of information about gender (Gelman, Taylor, & Nguyen, 2004) and natural kind categories (Gelman, Coley, Rosengren, Hartman, & Pappas, 1998)—even when adults do not intend to teach children specifically about these topics. In addition, children play an active role in obtaining information through conversation. By 2.5–3 years of age, children begin to actively seek knowledge from others by persistently asking causal questions of adults (Callanan & Oakes, 1992; Chouinard, 2007; Hood & Bloom, 1979). Even from this young age, children appear to be asking these "why" and "how" questions with the goal of obtaining explanations—they react with satisfaction when they get an explanation and are likely to repeat their question when they do not (Frazier, Gelman, & Wellman, 2009; see Lombrozo, Chapter 14).

However, the information provided by those around us is not always accurate, as informants may intentionally or unintentionally provide incorrect information. Again, children are not passive in this process. Children actively discriminate between different sources of information and choose from whom they should learn (or, alternatively, ignore).

Early work on children's attention to adult "testimony" was focused on word-learning tasks. For example, Koenig, Clément, and Harris (2004) asked children to observe two individuals: one who gave correct labels for familiar objects, and one who gave incorrect labels (e.g., stating, "That's a shoe" in reference to a ball). The children then saw the same two individuals naming a novel object with two different novel names ("That's a mido/toma"). When asked what the object is called ("Is this a mido or a toma?"), both 3- and 4-year-olds in this study picked the label from the accurate informant over the one provided by the previously inaccurate informant.

This methodology (choosing between two informants with conflicting claims) has been extended from word learning to a variety of tasks, including (but not limited to) causal inferences (Kushnir, Wellman, & Gelman, 2009), object functions (Birch, Vauthier, & Bloom, 2008), and emulation of actions (Birch, Akmal, & Frampton, 2010). This research has also explored many factors that affect which person's testimony children will choose to use to guide their learning. Children robustly attend to testimony from accurate informants across a variety of situations and types of knowledge. Preschoolers track the relative accuracy of informants (Pasquini, Corriveau, Koenig, & Harris, 2007), favoring those who provide the highest proportion of accurate answers. Three- and 4-year-olds are sensitive to not only what an informant knows but also whether that informant has been allowed to use that knowledge (e.g., when the knowledgeable informant has been blindfolded; Kushnir et al., 2009). Five-year-olds expect that an individual who provides the correct labels for familiar objects will also know more about words, will know more general facts, and, interestingly, will also behave more prosocially (Brosseau-Liard & Birch, 2010). Children are even willing to override their own observations when they conflict with the testimony being offered by a previously accurate informant (Jaswal, 2010; Ma & Ganea, 2010).

Children's ability to evaluate informants also demonstrates appropriate flexibility; information regarding the social characteristics of the informant interacts with information regarding their accuracy in the decisions children make about whom to believe. For example, children evaluate an expert as more knowledgeable than a nonexpert (Lutz & Keil, 2002). And when given the choice between a child and an adult informant, if both are accurate, 3- and 4-year-old children prefer the adult (Jaswal & Neely, 2006). However, if the adult provides inaccurate labels, preschool-aged children trust the testimony of a child over that of the inaccurate adult (Jaswal & Neely, 2006). In addition, providing trait labels (referring to an informant as "very good" or "not very good" at answering a question as opposed to "right" or "wrong") can lead 4-year-olds to prefer an accurate informant after only one trial (Fitneva & Dunfield, 2010). Even 2-year-old children use nonverbal cues from a single instance to select confident informants over informants who appear uncertain (Birch et al., 2010). However, an open question in this research concerns developmental changes in children's ability to critically evaluate the statements of deceptive individuals with self-serving motives (Heyman, 2008).

A larger open question for this body of research concerns how children's trust in testimony relates to their important social relationships. We know that preschoolers ask questions and that they are capable of focusing on the accuracy of testimony (even in the presence of other conflicting, tempting factors), but we do not yet know much about whose testimony children seek out and pay attention to within their everyday lives. A study by Corriveau et al. (2009) begins to explore this question in an interesting way. These researchers looked at the relationship between the attachment status of preschoolers and their willingness to accept their mother's versus a stranger's claims. The researchers found that children with secure attachment status preferred their mother's claims over that of the stranger (unless there were conflicting perceptual cues favoring the stranger's claim). However, regardless of the perceptual cues, children classified as having an avoidant attachment status were more likely to favor the stranger's claim over their mother's, and the children classified as reactive attachment status showed the opposite pattern (relying more on their mother's claims even with conflicting perceptual information that favored the stranger's claim).

Conclusions and Future Directions

Children's thinking is of broad interest to cognitive scientists, because it provides insight into fundamental issues concerning the building blocks of cognition, the role of experience, and how conceptual change comes about. As reviewed in this chapter, prior research provides a wealth of evidence regarding these issues. Nonetheless, many open questions remain. One set of questions concerns the early capacities in infancy that have been uncovered over the past 30 years. Increasingly sophisticated methods have revealed increasingly sophisticated understandings in preverbal infants, yet we still do not fully understand the basis of these capacities. What is innate, and what is learned rapidly during the first few months of life? Is early infancy a kind of critical period? In a related vein, what kinds of input should children receive at a young age? For example, to what extent do the first few months or years of life represent a special period during which rich exposure to different languages, faces, and so on is crucial, and to what extent can these capabilities be acquired later in development? Another puzzle raised by the findings of early capacities in infancy is why infants sometimes succeed on tasks that older children fail (e.g., theory of mind understanding; grasp of physical laws; e.g., Hood, Carey, & Prasada, 2000; Onishi & Baillargeon, 2005).

Another set of open issues stems from the finding that much of children's knowledge comes about from social interactions with others (Gelman, 2009). Clearly, social understanding plays a major role in cognitive understanding. This then raises the question of how children determine which sources of knowledge to attend to and learn from. Children must somehow sort out the different sources of knowledge, to figure out whom to believe and trust, and whom not to believe or trust. To what extent do (and should) children learn from media sources (e.g., TV, books, videos)? Other useful endeavors would be to integrate the research on testimony with research examining the questions children ask in informal learning contexts, and to investigate how children and adults work together to build an understanding of a phenomenon (e.g., Crowley et al., 2001; Siegel, Esterly, Callanan, Wright, & Navarro, 2007; see Callanan & Valle, 2008 for a related integration).

Finally, future research would benefit from examining cognitive development from new perspectives—both new from a comparative approach and new from a methodological approach. Examining children's thought in a variety of social and cultural contexts promises to reveal new insights. New advances are being made in examining what (if anything) is unique to humans versus other species. And of course it will be crucial to understand the neurological bases of cognitive performance and cognitive change.

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CHAPTER

27

The Human Enigma

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Abstract

Why is there such an enormous gap between human and nonhuman minds? Humans have been asking themselves this question for millennia. But if anything, the question has only become more enigmatic since Darwin and the genetic revolution. In the present chapter, we review the various answers that have been proposed to this question in recent years—from a "language instinct" and a "Theory of Mind" to the "massively modular" hypothesis—and argue that none of them provides a satisfactory solution to the enigma of the human mind.

Key Words: human mind, evolution, higher order relational reasoning, language, Theory of Mind, big brain, social intelligence hypothesis, language instinct

In most respects, we're a rather unimpressive animal. We're slow, weak, flat-footed, fragile, and flabby. We have big brains. But our social groups are mired in pointless conflict. Our eyesight and hearing pale in comparison to many bird-brained species. We can barely smell ourselves, let alone predators or prey. But it's been a few billion years since life first evolved on this planet. And in all that time, we're the only ones that have ever figured out how to light fires, sew, paint, call meetings, throw dinner parties, and send our children to school. Regardless of whether we want to admit it, there's something remarkable about the human mind.

Of course, our species' cognitive ability is hardly the only feature that distinguishes us from other animals. Compared to the rest of the great apes, we are also notable for our hairless sweaty skin, the unusual dexterity of our hands, the unique morphology of our eyes, our ability to swim, the prolonged helplessness of our children, and the peculiar biology of our sialic-acid-recognizing proteins, to mention only a few examples among many. But all these other differences between human and nonhuman apes pale in comparison to the discontinuity between human and nonhuman cognition.

So here's the enigma, perhaps the most profound enigma in cognitive science today: *Why is the gap between human and nonhuman minds so enormous?*

Humans have been asking themselves this question for a very long time—at least since the ancient Greeks and probably a lot longer than that. But if anything, the question has become even more enigmatic over the last century. Ever since Darwin, we have known that there is a profound biological continuity between humans and every other species. Indeed, we now know that the human species split off from other ape lineages just 5–6 million years ago—the blink of an eye on an evolutionary timescale. And we know that the vast majority of our DNA is identical to that of other living apes (Chimpanzee Sequencing and Analysis Consortium, 2005; Varki & Altheide, 2005). The more we learn about the biology of the human species, the more enigmatic our peculiar mental abilities become.