third edition

how children DEVELOP

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Theories of Cognitive Development

THEMES

Nature and Nurture

❖

The Active Child

❖

Continuity/Discontinuity

❖

Mechanisms of Change

❖

The Sociocultural Context

❖

Research and Children's Welfare

❖

A 7-month-old boy, sitting on his father's lap, becomes intrigued with the father's glasses, grabs one side of the frame, and yanks it. The father says, "Ow!" and his son lets go, but then reaches up and yanks the frame again. The father readjusts the glasses, but his son again grasps them and yanks. How, the father wonders, can he prevent his son from continuing this annoying routine without causing him to start screaming? Fortunately, the father, a developmental psychologist, soon realizes that Jean Piaget's theory of cognitive development suggests a simple solution: put the glasses behind his back. According to Piaget's theory, removing an object from a young infant's sight should lead the infant to act as if the object never existed. The strategy works perfectly; after the father puts the glasses behind his back, his son shows no further interest in them and turns his attention elsewhere. The father silently thanks Piaget.

This experience, which one of us actually had, illustrates in a small way how understanding theories of child development can yield practical benefits. It also illustrates three broader advantages of knowing about such theories:

1. Developmental theories provide a framework for understanding important phenomena. Theories help to reveal the significance of what we observe about children, both in research studies and in everyday life. Someone who witnessed the glasses incident but who did not know about Piaget's theory might have found the experience amusing but insignificant. Seen in terms of Piaget's theory, however, this passing event exemplifies a very general and profoundly important developmental phenomenon: infants below 8 months of age react to the disappearance of an object as though they do not understand that the object still exists. In this manner, theories of child development place particular experiences and observations in a larger context and deepen our understanding of their meaning.

2. Developmental theories raise crucial questions about human nature. Piaget's theory about young infants' reactions to disappearing objects was based on his informal experiments with infants younger than 8 months of age. Piaget would cover one of their favorite objects with a cloth or otherwise put it out of sight and then wait to see if they tried to retrieve the object. They rarely did, leading Piaget to conclude that before the age of 8 months, infants do not realize that hidden objects still exist. Other researchers have challenged this explanation. They argue that infants younger than 8 months do in fact understand that hidden objects continue to exist but lack the memory or problem-solving skills necessary for using that understanding to retrieve hidden objects (Baillargeon, 1993). Despite these disagreements about how best to interpret young infants' failure to retrieve hidden objects, researchers agree that Piaget's theory raises a crucial question about human nature: Do infants realize from the first days of life that objects continue to exist when out of sight, or is this something that they learn later? More significant, do young infants understand that people continue to exist when they cannot be seen? Do they fear that Mom has disappeared when she is no longer in sight?

3. Developmental theories lead to a better understanding of children. Theories also stimulate new research that may support the theories' claims, fail to support them, or require refinements of them, thereby improving our understanding of children. For example, Piaget's ideas led Munakata and her colleagues (1997) to test whether 7-month-olds' failure to reach for hidden objects was due to their lacking the motivation or the reaching skill to retrieve them. To find out, the researchers created a situation similar to Piaget's object-permanence experiment, except that they placed the object, an attractive toy, under a transparent cover rather than under an opaque one. In this situation, infants quickly removed the cover and regained the toy, thus demonstrating that they were both motivated to obtain it and sufficiently skilled to do so. This finding seemed to support Piaget's original interpretation. In contrast, an experiment conducted by Diamond (1985) indicated a need to revise Piaget's theory. Using an opaque covering, as Piaget did, Diamond varied the amount of time between when the toy was hidden and when the infant was allowed to reach for it. She found that even 6-month-olds could locate the toy if allowed to reach immediately, that 7-month-olds could wait as long as 2 seconds and still succeed, that 8-month-olds could wait as long as 4 seconds and still succeed, and so on. Diamond's finding indicated that memory for the location of hidden objects, as well as the understanding that they continue to exist, is crucial to success on the task. In sum, theories of child development are useful because they provide frameworks for understanding important phenomena, raise fundamental questions about human nature, and motivate new research that increases understanding of children.

ELIZABETH CREWS

The author whose son loved to grab his glasses is not the only one who has encountered this problem. If the parent in this picture had the good fortune to have read this textbook, she may have solved the problem in the same way.

Because child development is such a complex and varied subject, no single theory accounts for all of it. The most informative current theories focus primarily either on cognitive development or on social development. Providing a good theoretical account of development in either of these areas is an immense challenge, because each of them spans a huge range of topics. Cognitive development includes the growth of such diverse capabilities as perception, attention, language, problem solving, reasoning, memory, conceptual understanding, and intelligence. Social development includes the growth of equally diverse areas: emotions, personality, relationships with peers and family members, self-understanding, aggression, and moral behavior. Given this immense range of developmental domains, it is easy to understand why no one theory has captured the entirety of child development.

Therefore, we present cognitive and social theories in separate chapters. We consider theories of cognitive development in this chapter, just before the chapters on specific areas of cognitive development, and consider theories of social development in Chapter 9, just before the chapters on specific areas of social development.

This chapter examines five theoretical perspectives on cognitive development that are particularly influential: the Piagetian perspective, the information-processing perspective, the core-knowledge perspective, the sociocultural perspective, and the dynamic-systems perspective. We consider each perspective's fundamental assumptions about children's nature, the central developmental issues on which the perspective focuses, and practical examples of the perspective's usefulness for helping children learn.

These five theoretical perspectives are influential in large part because they provide important insights into the basic developmental themes described in Chapter 1. Each perspective addresses all the themes to some extent, but each emphasizes different ones. For example, Piaget's theory focuses on *continuity/discontinuity* and the *active child*, whereas information-processing theories focus on *mechanisms of change* (Table 4.1). Together, the five perspectives allow a broader appreciation of cognitive development than any one of them does alone.

TABLE 4.1

Main Questions Addressed by Theories of Cognitive Development

Theory	Main Question Addressed
Piagetian	Nature–nurture, continuity/discontinuity, the active child
Information-processing	Nature–nurture, how change occurs
Core-knowledge	Nature–nurture, continuity/discontinuity
Sociocultural	Nature–nurture, influence of the sociocultural context, how change occurs
Dynamic-systems	Nature–nurture, the active child, how change occurs

Piaget's Theory

Jean Piaget's studies of cognitive development are a testimony to how much one person can contribute to a scientific field. Before his work began to appear in the early 1920s, there was no recognizable field of cognitive development. Nearly a century later, Piaget's theory remains the best-known cognitive developmental theory in a field replete with theories. What accounts for its longevity?

One reason is that Piaget's observations and descriptions of children vividly convey the flavor of their thinking at different ages. Another reason is the exceptional breadth of the theory. It extends from the first days of infancy through adolescence and examines topics as diverse as conceptualization of time, space, distance, and number; language use; memory; understanding of other people's perspectives; problem solving; and scientific reasoning. Even today, it remains the most encompassing theory of cognitive development. Yet a third source of its longevity is that it offers an intuitively plausible depiction of the interaction of nature and nurture in cognitive development, as well as of the continuities and discontinuities that characterize intellectual growth.

YVES DEBRAINE / BLACK STAR

Jean Piaget, whose work has had a profound influence on developmental psychology, observing children at play.

View of Children's Nature

Piaget's fundamental assumption about children was that from birth onward they are active mentally as well as physically, and that their activity greatly contributes to their own development. His approach is often labeled *constructivist,* because it depicts children as constructing knowledge for themselves in response to their experiences. Three of the most important of children's constructive processes, according to Piaget, are generating hypotheses, performing experiments, and drawing conclusions from observations. If this description reminds you of scientific problem solving, you are not alone: the "child as scientist" is the dominant metaphor in Piaget's theory. Consider this description of his infant son:

> Laurent is lying on his back. . . . He grasps in succession a celluloid swan, a box, etc., stretches out his arm and lets them fall. He distinctly varies the position of the fall. When the object falls in a new position (for example, on his pillow), he lets it fall two or three more times on the same place, as though to study the spatial relation.
>
> (Piaget, 1952b, pp. 268–269)

In simple activities such as Laurent's game of "drop the toy from different places and see what happens," Piaget perceived the beginning of scientific experimentation.

This example also illustrates a second basic Piagetian assumption: Children learn many important lessons on their own, rather than depending on instruction from adults or older children. To further illuminate this point, Piaget cited a friend's recollection from childhood:

> He was seated on the ground in his garden and he was counting pebbles. Now to count these pebbles he put them in a row and he counted them one, two, three up to 10. Then he finished counting them and started to count them in the other direction. He began by the end and once again he found that he had 10. He found this marvelous. . . . So he put them in a circle and counted them that way and found 10 once again.
>
> (Piaget, 1964, p. 12)

This incident also highlights a third basic assumption of Piaget's: Children are intrinsically motivated to learn and do not need rewards from adults to do so. When they acquire a new capability, they apply it as often as possible. They also reflect on the lessons of their experience, because they want to understand themselves and everything around them.

Central Developmental Issues

In addition to his view that children actively shape their own development, Piaget offered important insights regarding the roles of nature and nurture and of continuities and discontinuities in development.

Nature and Nurture

Piaget believed that nature and nurture interact to produce cognitive development. In his view, nurture includes not just the nurturing provided by parents and other caregivers but every experience the child encounters. Nature includes the child's maturing brain and body; the child's ability to perceive, act, and learn from experience; and the child's motivation to meet two basic functions that are central to cognitive growth: adaptation and organization. **Adaptation** is the tendency to respond to the demands of the environment in ways that meet one's goals. **Organization** is the tendency to integrate particular observations into coherent knowledge. Because both adaptation and organization involve children's response to experience, it can be said that part of children's nature is to respond to their nurture.

Sources of Continuity

Piaget depicted development as involving both continuities and discontinuities. The main sources of continuity are three processes—*assimilation, accommodation*, and *equilibration*—that work together from birth to propel development forward.

Assimilation is the process by which people incorporate incoming information into concepts they already understand. To illustrate, when one of our children was 2 years old, he saw a man who was bald on top of his head and had long frizzy hair on the sides. To his father's great embarrassment, the toddler gleefully shouted, "Clown, clown." (Actually, it sounded more like "Kown, kown.") The man apparently looked enough like a "kown" that the boy could assimilate him to his clown concept.

Accommodation is the process by which people adapt their current understandings in response to new experiences. In the "kown" incident, the boy's father explained to his son that the man was not a clown and that even though his hair looked like a clown's, he was not wearing a funny costume and was not doing silly things to make people laugh. With this new information, the boy was able to accommodate his clown concept to the standard one, allowing other men with bald pates and long side hair to pass by in peace.

Equilibration is the process by which people balance assimilation and accommodation to create stable understanding. Equilibration includes three phases. First, children are satisfied with their understanding of a phenomenon; Piaget labeled this a state of *equilibrium,* because children do not see any discrepancies between their observations and their understanding of the phenomenon. Then, new information leads children to perceive that their understanding is inadequate. Piaget said that children at this point are in a state of *disequilibrium,* because they recognize shortcomings in their understanding of the phenomenon but cannot generate a superior alternative. Finally, children develop a more sophisticated understanding that eliminates the shortcomings of the old one. This new understanding provides

adaptation the tendency to respond to the demands of the environment in ways that meet one's goals

organization the tendency to integrate particular observations into coherent knowledge

assimilation the process by which people translate incoming information into a form that fits concepts they already understand

accommodation the process by which people adapt current knowledge structures in response to new experiences

equilibration the process by which children (or other people) balance assimilation and accommodation to create stable understanding

EVERETT COLLECTION

Perhaps toddlers yelling "Kown, kown" set Larry on his career path.

a more stable equilibrium, in the sense that a broader range of observations can be understood within it.

To illustrate how equilibration works, suppose that a 5-year-old girl believes that only animals are living things, because only they can move in ways that help them survive. (This is, in fact, what most 4- to 7-year-olds in a wide range of cultures believe [Inagaki & Hatano, 2008]; they know that plants grow and need food, but they do not conclude from this knowledge that plants are living things.) Sooner or later, the girl will realize that plants also move in ways that promote their survival (e.g., toward sunlight). This new information would be difficult for her to assimilate into her previous thinking. The resulting disparity between the girl's previous understanding of living things and her new knowledge about plants would create a state of disequilibrium, in which she was unsure what it means to be alive. Later, her thinking would accommodate to the new information about plants. That is, she would realize that animals and plants both move in adaptive ways and that because adaptive movement is a key characteristic of living things, plants as well as animals must be alive (Opfer & Gelman, 2001; Opfer & Siegler, 2004). This constitutes a more advanced equilibrium, because subsequent information about plants and animals will not contradict it. Through innumerable such equilibrations, children extend their understanding of the world around them.

Sources of Discontinuity

Although Piaget placed some emphasis on continuous aspects of cognitive development, the most famous part of his theory concerns discontinuous aspects, which he depicted as distinct *stages* of cognitive development. Piaget viewed these stages as products of the basic human tendency to organize knowledge into coherent structures. Each stage represents a coherent way of understanding one's experience, and each transition between stages represents a discontinuous intellectual leap from one coherent way of understanding to the next, higher one. The following are the central properties of Piaget's stage theory:

1. *Qualitative change.* Piaget believed that children of different ages think in qualitatively different ways. For example, he proposed that children in the early stages of cognitive development conceive of morality in terms of the consequences of a person's behavior, whereas children in later stages conceive of it in terms of the person's intent. A 5-year-old would judge someone who accidentally broke a whole jar of cookies as having been more naughty than someone who deliberately stole a single cookie; an 8-year-old would have the opposite assessment. This difference represents a *qualitative change,* because the two children are basing their moral judgments on entirely different criteria.

2. *Broad applicability.* The type of thinking characteristic of each stage influences children's thinking across diverse topics and contexts.

3. *Brief transitions.* Before entering a new stage, children pass through a brief transitional period in which they fluctuate between the type of thinking characteristic of the new, more advanced stage and the type of thinking characteristic of the old, less advanced one.

4. *Invariant sequence.* Everyone progresses through the stages in the same order and never skips a stage.

Piaget hypothesized that people progress through four stages of cognitive development: the *sensorimotor* stage, the *preoperational* stage, the *concrete operational* stage, and the *formal operational* stage. In each stage, children exhibit new abilities that allow them to understand the world in qualitatively different ways than they had previously.

1. In the **sensorimotor stage** (birth to age 2 years), infants' intelligence develops, and is expressed, through their sensory and motor abilities. They use these abilities to perceive and explore the world around them, gaining information about the objects and people in it and constructing rudimentary forms of fundamental concepts such as time, space, and causality. Throughout the sensorimotor period, infants live largely in the here and now: their intelligence is bound to their immediate perceptions and actions.
2. In the **preoperational stage** (ages 2 to 7 years), toddlers and preschoolers become able to represent their experiences in language and mental imagery. This allows them to remember the experiences for longer periods of time and to form more sophisticated concepts. However, as suggested by the term *preoperational,* Piaget's theory emphasizes young children's inability to perform *mental operations*, that is, forms of reasoning that are part of an organized system of mental activities. Lacking such well-organized systems, children are unable to form certain ideas, such as the idea that pouring water from one glass into a differently shaped glass does not change the amount of water.
3. In the **concrete operational stage** (ages 7 to 12 years), children can reason logically about concrete objects and events; for example, they understand that pouring water from one glass to a differently shaped one leaves the amount of water unchanged. However, they have difficulty thinking in purely abstract terms and in generating scientific experiments to test their beliefs.
4. In the final stage of cognitive development, the **formal operational stage** (age 12 years and beyond), children can think deeply not only about concrete events but also about abstractions and purely hypothetical situations. They also can perform systematic scientific experiments and draw appropriate conclusions from them, even when the conclusions differ from their prior beliefs.

With this overview of Piaget's theory, we can consider in greater depth some of the major changes that take place in each stage.

The Sensorimotor Stage (Birth to Age 2 Years)

One of Piaget's most profound insights was his realization that the roots of adult intelligence are present in infants' earliest behaviors, such as their seemingly aimless sucking, flailing, and grasping. He recognized that these behaviors are not random but instead reflect an early type of intelligence involving sensory and motor activity. Indeed, many of the clearest examples of the *active child* theme come from Piaget's descriptions of the development of what he called "sensorimotor intelligence."

Over the course of the first two years, according to Piaget, infants' sensorimotor intelligence develops tremendously. The sheer amount of change may at first seem astonishing. However, when we consider the immense variety of new experiences that infants encounter during this period, and the tripling of brain weight between birth and age 3 (with weight being an index of brain development during this period), the huge increase in infants' cognitive abilities seems more comprehensible. The profound developments that Piaget described as occurring during infancy call

sensorimotor stage the period (birth to 2 years) within Piaget's theory in which intelligence is expressed through sensory and motor abilities

preoperational stage the period (2 to 7 years) within Piaget's theory in which children become able to represent their experiences in language, mental imagery, and symbolic thought

concrete operational stage the period (7 to 12 years) within Piaget's theory in which children become able to reason logically about concrete objects and events

formal operational stage the period (12 years and beyond) within Piaget's theory in which people become able to think about abstractions and hypothetical situations


DAVID YOUNG-WOLFF / PHOTOEDIT

Piaget proposed that when infants suck on objects, they not only gain pleasure but also knowledge about the world beyond their bodies.

attention to a general principle: Children's thinking grows especially rapidly in the first few years.

Infants are born with many reflexes. When objects move in front of their eyes, they visually track them; when objects are placed in their mouths, they suck them; when objects come into contact with their hands, they grasp them; when they hear noises, they turn their heads toward them; and so on. Piaget believed that these simple reflexes and perceptual abilities are essential tools for building intelligence.

Even during their first month, infants begin to modify their reflexes to make them more adaptive. At birth, for example, they suck in a similar way regardless of what they are sucking. Within a few weeks, however, they adjust their sucking according to the object in their mouth. Thus, they suck on a milk-yielding nipple in a way that enhances the efficiency of their feeding and that is notably different from the way they suck on a finger or even a pacifier. As this example illustrates, from the first days out of the womb, infants accommodate their actions to the parts of the environment with which they interact.

Over the course of the first few months, infants begin to organize separate reflexes into larger behaviors, most of which are centered on their own bodies. Instead of having two separate reflexes, one of grasping objects that touch their palms and another of sucking on objects that come into their mouths, infants become able to integrate these actions. When an object touches their palm, they can grasp it and bring it to their mouth. Thus, their reflexes serve as building blocks for more complex behaviors.

In the middle of their first year, infants become increasingly interested in the world around them—people, animals, toys, and other objects and events beyond their own bodies. A hallmark of this shift is the repetition of actions on the environment that produce pleasurable or interesting results. Repeatedly banging rattles, for example, is a favorite activity for many infants at this time.

Piaget (1954) made a striking and controversial claim about a deficiency in infants' thinking during this period—the one referred to in the chapter-opening anecdote about the father hiding his glasses. The claim was that through the age of 8 months, infants lack **object permanence,** the knowledge that objects continue to exist even when they are out of view. This claim was based largely on Piaget's observations of his own children, Laurent, Lucienne, and Jacqueline. The following account of an experiment with Laurent reflects the type of observation that inspired Piaget's belief about object permanence:

> At age 7 months, 28 days, I offer him a little bell behind a cushion. So long as he sees the little bell, however small it may be, he tries to grasp it. But if the little bell disappears completely he stops all searching. I then resume the experiment using my hand as a screen. Laurent's arm is outstretched and about to grasp the little bell at the moment I make it disappear behind my hand which is open and at a distance of about 15 cm. from him. He immediately withdraws his arm, as though the little bell no longer existed.
>
> (Piaget, 1954, p. 39)

Thus, in Piaget's view, for infants younger than 8 months, the adage "out of sight, out of mind" is literally true. They are able to mentally represent only objects that they can perceive at the moment.

By the end of the first year, infants search for hidden objects rather than act as if they had vanished, thus indicating that they mentally represent the objects' continuing existence even when they no longer see them. These initial representations of objects are fragile, however, as reflected in the **A-not-B error.** In this error, once

object permanence the knowledge that objects continue to exist even when they are out of view

A-not-B error the tendency to reach for a hidden object where it was last found rather than in the new location where it was last hidden

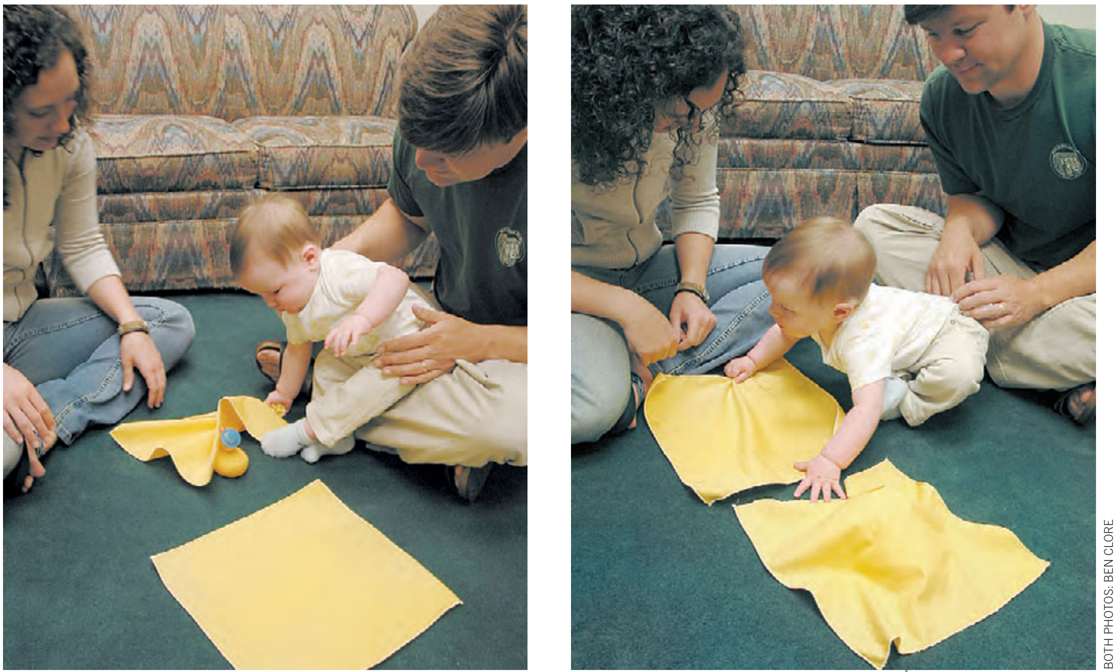


FIGURE 4.1 Piaget's A-not-B task
A child looks for and finds a toy under the cloth where it was hidden (left frame). After several such experiences, the toy is hidden in a different location (right frame). The child continues to look where he found the toy previously rather than where it is hidden now. The child's ignoring the visible protrusion of the toy under the cloth in the right frame illustrates the strength of the inclination to look in the previous "hiding place."

8- to 12-month-olds have reached for and found a hidden object several times in one place (location A), when they see the object hidden at a different place (location B) and are prevented from immediately searching for it, they tend to reach where they initially found the object (see Figure 4.1). Not until around their first birthday do infants consistently search first at the object's current location.

At around 1 year of age, infants begin to actively and avidly explore the potential ways in which objects can be used. The "child as scientist" example presented earlier, in which Piaget's son Laurent varied the positions from which he dropped different objects to see what would happen, provides one instance of this emerging competency. Similar examples occur in every family with infants. Few parents forget their 12- to 18-month-olds' sitting in their high chairs, banging various objects against the chair's tray—first a spoon, then a plate, then a cup—seemingly fascinated by the distinctive sounds made by the different objects. Nor do they forget their infants' dropping various bathroom articles into the toilet, or showering a bag of flour over the kitchen floor, just to see what happens. Piaget regarded such actions not as bad behavior but rather as the beginnings of scientific experimentation.

In the last half year of the sensorimotor stage (ages 18 to 24 months), according to Piaget, infants become able to form enduring mental representations. The first sign of this new capability is **deferred imitation,** that is, the repetition of other people's behavior minutes, hours, or even days after it occurred. Consider Piaget's observation of 1-year-old Jacqueline:

> Jacqueline had a visit from a little boy . . . who, in the course of the afternoon, got into a terrible temper. He screamed as he tried to get out of a playpen and pushed it backward, stamping his feet. . . . The next day, she herself screamed in her playpen and tried to move it, stamping her foot lightly several times in succession.
> (Piaget, 1951, p. 63)

deferred imitation the repetition of other people's behavior a substantial time after it originally occurred


COURTESY OF JUDY DELOACHE

This toddler's techniques for applying eye makeup may not exactly mirror those he has seen his mother use, but they are close enough to provide a compelling illustration of deferred imitation, a skill that children gain during their second year.

Piaget indicated that Jacqueline had never before thrown such a tantrum. Presumably, she had watched and remembered her playmate's behavior, maintained a representation of it overnight, and imitated it the next day.

When we consider Piaget's whole account of cognitive development during infancy, several notable trends are evident. At first, infants' activities center on their own bodies; later, their activities include the world around them. Early goals are concrete (shaking a rattle and listening to the sound it makes); later goals often are more abstract (varying the heights from which objects are dropped and observing how the effects vary). Infants also become increasingly able to form mental representations, moving from "out of sight, out of mind" to remembering a playmate's actions from a full day earlier. Such enduring mental representations make possible the next stage, preoperational thinking.

The Preoperational Stage (Ages 2 to 7)

Piaget viewed the preoperational period as including a mix of striking cognitive acquisitions and even more striking limitations. Perhaps the foremost acquisition is the development of *symbolic representations;* among the most notable weaknesses are *egocentrism* and *centration.*

Development of Symbolic Representations

Have you ever seen preschoolers use two popsicle sticks to represent a gun or a banana to represent a telephone? Forming such personal symbols is common among 3- to 5-year-olds. It is one of the ways in which they exercise their emerging capacity for **symbolic representation**—the use of one object to stand for another. Typically, these personal symbols physically resemble the objects they represent. The popsicle sticks' and banana's shape somewhat resemble those of a gun and a telephone receiver.

As children develop, they rely less on self-generated symbols and more on conventional ones. For example, when 5-year-olds play games involving pirates, they might wear a patch over one eye and a bandana over their head because that is the way pirates are commonly depicted. Heightened symbolic capabilities during the preoperational period are also evident in the growth of drawing. Children's drawings between ages 3 and 5 make increasing use of symbolic conventions, such as representing the leaves of flowers as V's (Figure 4.2).

FIGURE 4.2 A 4-year-old's drawing of a summer day Note the use of simple artistic conventions, such as the V-shaped leaves on the flowers (Dennis, 1992, p. 234).

Egocentrism

Although Piaget noted important growth in children's thinking during the preoperational stage, he found the limitations of this period to be more intriguing, and more revealing of children's preoperational understanding. As noted, one important limitation is **egocentrism,** that is, perceiving the world solely from one's own point of view. An example of this limitation involves preschoolers' difficulty in taking other people's spatial perspectives. Piaget and Inhelder (1956) demonstrated this difficulty by having 4-year-olds sit at a table in front of a model of three mountains of different sizes (Figure 4.3). The children were asked to identify which of several photographs depicted what a doll would see if it were sitting on chairs at various locations around the table. Solving this problem required children to recognize that their own perspective was not the only one possible and to imagine what the view would be from another location. Most 4-year-olds, according to Piaget, cannot do this.

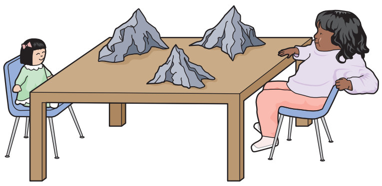


FIGURE 4.3 Piaget's three-mountains task When asked to choose the picture that shows what the doll sitting in the seat across the table would see, most children below age 6 choose the picture showing how the scene looks to them, illustrating their difficulty in separating their own perspective from that of others.

The same difficulty in taking other people's perspectives is seen in quite different contexts, for example, in communication. As illustrated in Figure 4.4, preschoolers often talk right past each other; they seem blithely unaware that their listener is paying no attention whatsoever to what they are saying. Preschoolers' egocentric communication also is evident when they make statements that assume knowledge that they themselves possess but that their listeners lack. For example, 2- and 3-year-olds frequently tell preschool teachers or parents things like, "He took it from me," in situations where the adult has no idea what person or object the child is referring to. Egocentric thinking is also evident in preschoolers' explanations of events and behavior. Consider the following interviews with preschoolers that occurred in the original version of the TV show *Kids Say the Darndest Things:*

> *Interviewer:* Any brothers or sisters?
> *Child:* I have a brother a week old.
> *I:* What can he do?
> *C:* He can say "Mamma" and "Daddy."
> *I:* Can he walk?
> *C:* No, he's too lazy.
>
> *Interviewer:* Any brothers or sisters?
> *Child:* A 2-months-old brother.
> *I:* How does he behave?
> *C:* He cries all night.
> *I:* Why is that, do you think?
> *C:* He probably thinks he's missing something on television.
>
> (Linkletter, 1957, p. 6)

Over the course of the preoperational period, egocentric speech becomes less common. An early sign of progress is children's verbal quarrels, which become increasingly frequent during this period. The fact that a child's statements elicit a playmate's disagreement indicates that the playmate is at least paying attention to the differing perspective that the other child's comment implies. Children also become better able to envision spatial perspectives other than their own during the preoperational period. Of course, we all remain somewhat egocentric throughout our lives, but most of us do improve.

Centration

A related limitation of preschoolers' thinking is **centration,** that is, focusing on a single, perceptually striking feature of an object or event to the exclusion of other relevant but less striking features. Children's approaches to balance-scale problems provide a good example of centration. If presented with a balance scale like that in Figure 4.5 and asked "Which side will go down?," 5- and 6-year-olds center on the amount of weight on each side, ignore the distance of the weights from the fulcrum, and say that whichever side has more weight will go down (Inhelder & Piaget, 1958).

Another good example of centration comes from Piaget's research on children's understanding of conservation. The idea of the **conservation concept** is that merely changing the appearance or arrangement of objects does not necessarily change their key properties, such as quantity of material. Three variants of the concept that are commonly studied in 5- to 8-year-olds are conservation of liquid quantity, conservation of solid quantity, and conservation of number (Piaget, 1952a). In all three cases, the tasks used to measure children's understanding

symbolic representation the use of one object to stand for another

egocentrism the tendency to perceive the world solely from one's own point of view

centration the tendency to focus on a single, perceptually striking feature of an object or event

conservation concept the idea that merely changing the appearance of objects does not change their key properties

FIGURE 4.4 Egocentrism An example of young children's egocentric conversations.

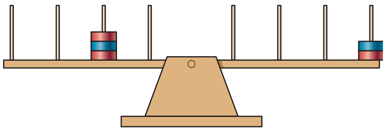


FIGURE 4.5 The balance scale When asked to predict which side of a balance scale, like the one shown above, would go down if the arm were allowed to move, 5- and 6-year-olds almost always center their attention on the amount of weight and ignore the distances of the weights from the fulcrum. Thus, they would predict that the left side would go down, although the right side actually would.

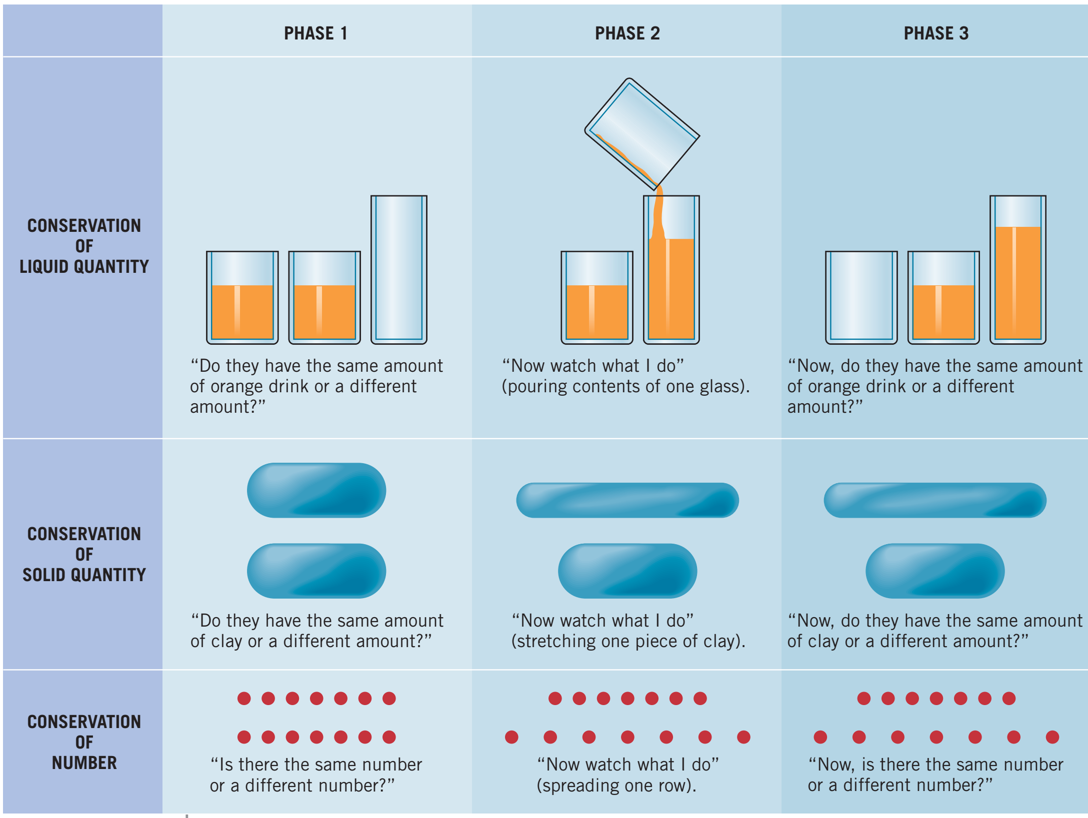


FIGURE 4.6 Procedures used to test conservation of liquid quantity, solid quantity, and number Most 4- and 5-year-olds say that the taller liquid column has more liquid, the longer sausage has more clay, and the longer row has more objects.

employ a three-phase procedure (Figure 4.6). First, as in the figure, children see two objects or sets of objects—two glasses of orangeade, two clay sausages, or two rows of pennies—that are identical in number or quantity. Once children agree that the dimension of interest (e.g., the amount of orangeade) is equal in both items, the second phase follows. Here, children observe a transformation of one object or set of objects that makes it look different but does not change the dimension in question. A glass of orangeade might be poured into a taller, narrower, glass; a short, thick clay sausage might be molded into a long, thin sausage; or a row of pennies might be lengthened. Finally, in the third phase, children are asked whether the dimension of interest, which they earlier had said was equal for the two objects or sets of objects, is still equal.

The large majority of 4- and 5-year-olds answer "no." On conservation-of-liquid-quantity problems, they claim that the taller, narrower glass has more orangeade; on conservation-of-solid-quantity problems, they claim that the long, thin sausage has more clay than the short, thick one; and so on. Children of this age make similar errors in everyday contexts; for example, they often think that if a child has one fewer cookie than another child, a fair solution is to break one of the short-changed child's cookies into two pieces (Miller, 1984).

A variety of weaknesses that Piaget perceived in preoperational thinking contribute to these difficulties with conservation problems. Preoperational thinkers center their attention on the single, perceptually salient dimension of height or length, ignoring other relevant dimensions. In addition, their egocentrism leads to their failing to understand that their own perspective can be misleading—that just because a tall narrow glass of orangeade or a long thin clay sausage looks as though it has more orangeade or clay than a shorter, wider one does not mean that it really does. Children's tendency to focus on static states of objects (the appearance of the objects before and after the transformation) and to ignore the transformation that was performed (pouring the orangeade or reshaping the clay) also contributes to their difficulty in solving conservation problems.

In the next period of cognitive development, the concrete operations stage, children largely overcome these and other related limitations.

The Concrete Operations Stage (Ages 7 to 12)

At around age 7, according to Piaget, children begin to reason logically about concrete features of the world. Development of the conservation concept exemplifies this progress. Although few 5-year-olds solve any of the three conservation tasks described in the previous section, most 7-year-olds solve all of them. The same progress in thinking also allows children in the concrete operations stage to solve many other problems that require attention to multiple dimensions. For example, on the balance-scale problem, they consider distance from the fulcrum as well as weight.

However, this relatively advanced reasoning is, according to Piaget, limited to concrete situations. Thinking systematically remains very difficult, as does reasoning about hypothetical situations. These limitations are evident in the types of experiments that concrete operational children perform to solve the pendulum problem (Inhelder & Piaget, 1958) (Figure 4.7). In this problem, children are presented a pendulum frame, a set of strings of varying length with a loop at each end, and a set of metal weights of varying weight, any of which can be attached to any string. When the loop at one end of the string is attached to a weight, and the loop at the other end is attached to the frame of the pendulum, the string can be swung. The task is to perform experiments that indicate which factor or factors influence the amount of time it takes the pendulum to swing through a complete arc. Is it the length of the string, the heaviness of the weight, the height from which the weight is dropped, or some combination of these factors? Think for a minute: How would you go about solving this problem?

Most concrete operational children begin their experiments believing that the heaviness of the weight is the most important factor, quite likely the only important one. This belief is not unreasonable; indeed, most adolescents and adults share it. What distinguishes the children's reasoning from that of older individuals lies in how they test their beliefs. Typically, children design unsystematic experiments from which no clear conclusion can be drawn. For example, they might compare the travel time of a heavy weight on a short string dropped from a high position to the travel time of a light weight on a long string dropped from a lower position. When the first string goes faster, they conclude that, just as they had thought, heavy weights go faster. This premature conclusion, however, reflects their limited ability to think systematically or to imagine all possible combinations of variables; they do not seem to imagine that the faster motion might reflect the length of the string or the height from which the string was dropped, rather than the weight of the object.

The Formal Operations Stage (Age 12 and Beyond)

Formal operational thinking, which includes the ability to think abstractly and to reason hypothetically, is the pinnacle of the Piagetian stage progression. The

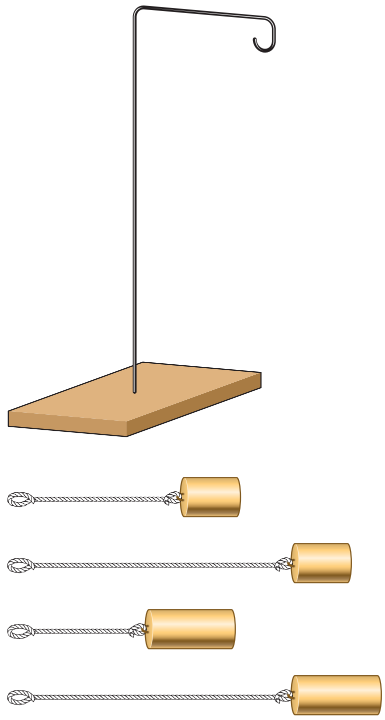
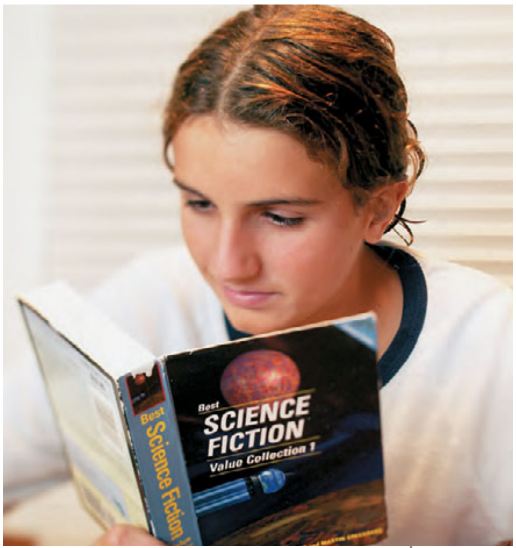


FIGURE 4.7 Inhelder and Piaget's pendulum problem The task is to compare the motions of longer and shorter strings, with lighter and heavier weights attached, in order to determine the influence of weight, string length, and dropping point on the time it takes for the pendulum to swing back and forth. Children below age 12 usually perform unsystematic experiments and draw incorrect conclusions.



MARK RICHARDS / PHOTOEDIT

Teenagers' emerging ability to understand that the reality in which they live is only one of many possible realities contributes to many of them developing a taste for science fiction.

difference between reasoning in this stage and in the previous one is clearly illustrated by formal operational reasoners' approach to the pendulum problem. Framing the problem more abstractly than do children in the concrete operations stage, they see that any of the variables—weight, string length, and dropping point—might influence the time it takes for the pendulum to swing through an arc, and that it therefore is necessary to test the effect of each variable systematically. To test the effect of weight, they compare times to complete an arc for a heavier weight and a lighter weight, attached to strings of equal length and dropped from the same height. To test the effect of string length, they compare the travel times of a long and a short string, with equal weight dropped from the same position. To test the influence of dropping point, they vary the dropping point of a given weight attached to a given string. Such a systematic set of experiments allows the formal operational reasoner to determine that the only factor that influences the pendulum's travel time is the length of the string; neither weight nor dropping point matters.

Piaget believed that unlike the previous three stages, the formal operations stage is not universal: not all adolescents (or adults) reach it. For those adolescents who do reach it, however, formal operational thinking greatly expands and enriches their intellectual universe. Such thinking makes it possible for them to see the particular reality in which they live as only one of an infinite number of possible realities. This insight leads them to think about alternative ways that the world could be and to ponder deep questions concerning truth, justice, and morality. It no doubt also helps account for the fact that many people first acquire a taste for science fiction during adolescence. The alternative worlds depicted in science-fiction stories appeal to adolescents' emerging capacity to think about the world they know as just one of many possibilities and to wonder whether a better world is possible. Inhelder and Piaget (1958) aptly expressed the intellectual power that formal operational thinking provides adolescents: "Each one has his own ideas (and usually he believes they are his own) which liberate him from childhood and allow him to place himself as the equal of adults" (pp. 340–341).

The attainment of such systematic formal operational reasoning does not mean that adolescents will always reason in advanced ways, but it does, according to Piaget, mark the point at which adolescents attain the reasoning powers of intelligent adults. (Some ways in which Piaget's theory can be applied to improving education are discussed in Box 4.1.)

Piaget's Legacy

Although much of Piaget's theory was formulated many years ago, it remains a very influential approach to cognitive development. Some of its strengths were mentioned earlier. It provides a good overview, with countless fascinating observations, of what children's thinking is like at different points in development (see Table 4.2). It offers a plausible and appealing perspective on children's nature. It surveys a remarkably broad spectrum of developments and covers the entire age span from infancy through adolescence.

However, subsequent analyses (Flavell, 1971, 1982; Miller, 2002) have also identified some crucial weaknesses in Piaget's theory. The following four weaknesses are particularly important:

1. The stage model depicts children's thinking as being more consistent than it is. According to Piaget, once children enter a given stage, their thinking consistently shows the

applications 4.1

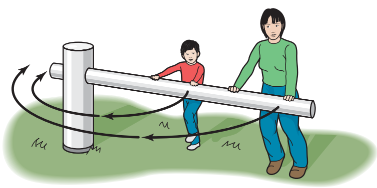
Educational Applications of Piaget's Theory

Piaget's view of children's cognitive development holds a number of general implications for how children should be educated (Ginsburg & Opper, 1988; Piaget, 1970). Most generally, it suggests that children's distinctive ways of thinking at different ages need to be considered in deciding how to teach them. For example, children in the concrete operational stage would not be expected to be ready to learn purely abstract concepts such as inertia and equilibrium state, whereas adolescents in the formal operational stage would be. Taking into account such general age-related differences in cognitive level before deciding when to teach particular concepts is often labeled a "child-centered approach."

A second implication of Piaget's approach is that children learn by interacting with the environment, both mentally and physically. One research demonstration of this principle involved promoting children's understanding of the concept of speed (Levin et al., 1990). The investigation focused on problems of a type beloved by physics teachers: "When a race horse travels around a circular track, do its right and left sides move at the same speed?" It appears obvious that they do, but in fact they do not. The part of the horse toward the outside of the track is covering a slightly greater distance in the same amount of time as the part toward the inside and therefore is moving slightly faster.

Levin and her colleagues devised a procedure that allowed children to actively experience how different parts of a single object can move at different speeds. They attached one end of a 7-foot-long metal bar to a pivot that was mounted on the floor. Then, one by one, 6th graders and an experimenter took four walks around the pivot while holding onto the bar. On two of the walks, the child held the bar near the pivot and the experimenter held it at the far end; on the other two walks, they switched positions (see figure). After each walk, children were asked whether they or the experimenter had walked faster.

The differences in the speeds required for walking while holding the inner and the outer parts of the metal bar were so dramatic that the children generalized their new understanding to other problems involving circular motion, such as cars moving around circular tracks on a computer screen. In other words, physically experiencing the concept accomplished what years of formal science instruction usually fail to do. As one boy said, "Before, I hadn't experienced it. I didn't think about it. Now that I have had that experience, I know that when I was on the outer circle, I had to walk faster to be at the same place as you" (Levin et al., 1990). Clearly, relevant physical activities, accompanied by questions that call attention to the lessons of the activities, can foster children's learning.



A child and an adult holding onto a bar as they walk around a circle four times. On the first two trips around, the child holds the bar near the pivot; on the second two, the child holds it at its end. The much faster pace needed to keep up with the bar when holding onto its end led children to realize that the end was moving faster than the inner portion (Levin, Siegler, & Druyan, 1990).

TABLE 4.2

Piaget's Stages of Cognitive Development

Stage	Approximate Age	New Ways of Knowing
Sensorimotor	Birth to 2 years	Infants know the world through their senses and through their actions. For example, they learn what dogs look like and what petting them feels like.
Preoperational	2–7 years	Toddlers and young children acquire the ability to internally represent the world through language and mental imagery. They also begin to be able to see the world from other people's perspectives, not just from their own.
Concrete operational	7–12 years	Children become able to think logically, not just intuitively. They now can classify objects into coherent categories and understand that events are often influenced by multiple factors, not just one.
Formal operational	12 years onward	Adolescents can think systematically and reason about what might be as well as what is. This allows them to understand politics, ethics, and science fiction, as well as to engage in scientific reasoning

characteristics of that stage across diverse concepts. Subsequent research, however, has shown that children's thinking is far more variable than this depiction suggests. For example, most children succeed on conservation-of-number problems by age 6, whereas most do not succeed on conservation-of-solid-quantity problems until age 8 or 9 (Field, 1987). Piaget recognized that such variability exists but was unable to explain it successfully.

2. Infants and young children are more cognitively competent than Piaget recognized. Piaget presented children with relatively difficult tests of understanding. This led him to miss infants' and young children's earliest knowledge of these concepts. For example, Piaget's test of object permanence required children to reach for the hidden object several seconds after it is hidden; as Piaget claimed, children do not do this until 8 or 9 months of age. However, alternative tests of object permanence, which analyze infants' eye fixations immediately after the object has disappeared from view, indicate that infants have some grasp of the continuing existence of objects by 3 months of age (Baillargeon, 1987; 1993).

3. Piaget's theory understates the contribution of the social world to cognitive development. Piaget's theory focuses on how children come to understand the world through their own efforts. From the day that children emerge from the womb, however, they live in an environment of adults and older children who shape their cognitive development in countless ways. A child's cognitive development reflects the contributions of other people, as well as of the broader culture, to a far greater degree than Piaget's theory acknowledges.

4. Piaget's theory is vague about the cognitive processes that give rise to children's thinking and about the mechanisms that produce cognitive growth. Piaget's theory provides any number of excellent descriptions of children's thinking. It is less revealing, however, about the processes that lead children to think in a particular way and that produce changes in their thinking. Assimilation, accommodation, and equilibration have a general air of plausibility, but how they operate is far from clear.

These weaknesses of Piaget's theory do not negate the magnitude of his achievement: it remains one of the major intellectual accomplishments of the twentieth century. However, appreciating the weaknesses as well as the strengths of his theory is necessary for understanding why alternative theories of cognitive development have become increasingly prominent.

In the remainder of this chapter, we consider the four most prominent alternative theories: *information-processing, dynamic-systems, core-knowledge,* and *sociocultural.* Each type of theory can be seen as an attempt to overcome a major weakness of Piaget's approach. Information-processing theories emphasize precise characterizations of the processes that give rise to children's thinking and the mechanisms that produce cognitive growth. Core-knowledge theories emphasize infants' and young children's early understandings that may have an innate, evolutionary basis. Sociocultural theories emphasize the ways in which children's interactions with the social world, both with other people and with the products of their culture, guide cognitive development. Dynamic-systems theories emphasize the variability of children's behavior and how the child's developing physical and mental capabilities and the particulars of the situation contribute to that variability. In addition, theorists of all four persuasions agree that children's thinking is more variable than Piaget's stage theory suggests.

review:

Piaget's theory of cognitive development emphasizes the interaction of nature and nurture, continuities and discontinuities, and children's active contribution to their own development. Piaget believed that a maturing brain, growing abilities to perceive and act, and increasingly rich and varied experiences interacting with the environment allow children to adapt to an expanding range of circumstances.

According to Piaget, the continuities of development are produced by assimilation, accommodation, and equilibration. Assimilation involves adapting incoming information to fit current understanding. Accommodation involves adapting one's thinking toward being more consistent with new experiences. Equilibration involves balancing assimilation and accommodation in a way that creates stable understandings.

As depicted by Paiget, the discontinuities of cognitive development involve four discrete stages: the sensorimotor stage (birth to age 2), in which infants begin to know the world through the perceptions of their senses and through their motor activities; the preoperational stage (ages 2 to 7), in which children become capable of mental representations but tend to be egocentric and to focus on a single dimension of an event or problem; the concrete operational stage (ages 7 to 12), in which children reason logically about concrete aspects of the environment but have difficulty thinking abstractly; and the formal operational stage (age 12 and beyond), in which preadolescents and adolescents become capable of abstract thought.

Among the most important strengths of Piaget's theory are its broad overview of development, its plausible and attractive perspective on children's nature, its inclusion of varied tasks and age groups, and its endlessly fascinating observations. Among the theory's most important weaknesses are its overstatement of the consistency of children's thinking, its underestimation of infants' and young children's cognitive competence, its lack of attention to the contribution of the social world, and its vagueness regarding cognitive mechanisms.

Information-Processing Theories

SCENE: DAUGHTER AND FATHER IN THEIR YARD. A PLAYMATE RIDES IN ON A BIKE

Child: Daddy, would you unlock the basement door?
Father: Why?
C: 'Cause I want to ride my bike.
F: Your bike is in the garage.
C: But my socks are in the dryer.

(Klahr, 1978, pp. 181–182)

What reasoning could have produced this girl's enigmatic comment, "But my socks are in the dryer"? David Klahr, an eminent information-processing theorist, formulated the following model of the thought process that led to it:

Top goal: I want to ride my bike.
  Bias: I need shoes to ride comfortably.
  Fact: I'm barefoot.

Subgoal 1: Get my sneakers.
  Fact: The sneakers are in the yard.
  Fact: They're uncomfortable on bare feet.

task analysis the research technique of identifying goals, relevant information in the environment, and potential processing strategies for a problem

structure the basic organization of the cognitive system, including its main components and their characteristics

processes the specific mental activities, such as rules and strategies, that people use to remember and to solve problems

Subgoal 2: Get my socks.
  Fact: The sock drawer was empty this morning.
  Inference: The socks probably are in the dryer.

Subgoal 3: Get them from the dryer.
  Fact: The dryer is in the basement.

Subgoal 4: Go to the basement.
  Fact: It's quicker to go through the yard entrance.
  Fact: The yard entrance is always locked.

Subgoal 5: Unlock the door to the basement.
  Fact: Daddies have the keys to everything.

Subgoal 6: Ask Daddy to unlock the door.

Klahr's analysis of his daughter's thinking illustrates several notable characteristics of information-processing theories.[1] One is the precise specification of the processes involved in children's thinking. Klahr attempted to identify his daughter's exact goals, the environmental obstacles she anticipated, and the reasoning that led her to the strategy of asking him to unlock the basement door.

Klahr's approach is referred to as **task analysis**—that is, the identification of goals, relevant information in the environment, and potential processing strategies. Such an approach helps information-processing researchers understand and predict children's behavior and allows them to perform rigorous experimental tests of precise hypotheses regarding how development occurs. In some cases, it also allows them to formulate computer simulations, a type of mathematical model that expresses ideas about mental processes in particularly unambiguous ways. For example, Klahr and Wallace (1976) formulated computer simulations of the knowledge and mental processes that led young children to fail on conservation problems and of the somewhat different knowledge and mental processes that allowed older children to succeed on them.

A second distinctive feature that is evident in Klahr's information-processing analysis is an emphasis on thinking as an activity that occurs over time, with numerous distinct mental operations underlying a single behavior. In his analysis, Klahr depicts his daughter as generating a sequence of subgoals, inferences, and relevant facts, one after another, in planning how to reach the overall goal of riding her bike in comfort.

A third distinctive characteristic of information-processing theories is their emphasis on structure and processes. **Structure** refers to the basic organization of the cognitive system, including the main components of the system and their characteristics. Increasingly, information-processing approaches are linking hypothesized cognitive structures to specific brain areas (see Figure 4.8 on page 147). **Processes** refer to the vast number of specific mental activities, such as the use of rules and strategies, that people devise to aid memory and solve problems. Which rules and strategies children use, and how those rules and strategies change with age and experience, are among the major issues addressed by information-processing approaches.

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[1] Here and throughout this section, we use the plural term "information-processing *theories*" rather than the singular term "information-processing *theory*" because information theories consist of a variety of related approaches, rather than reflecting the unified ideas of a single theorist such as Piaget. For the same reason, in subsequent sections we refer to "core-knowledge theories," "sociocultural theories," and "dynamic-systems theories."

View of Children's Nature

Information-processing theorists view children as undergoing continuous cognitive change. That is, they see children's cognitive growth as occurring constantly, in small increments, rather than broadly and abruptly. This depiction differs from Piaget's belief that children progress through qualitatively distinct, broadly applicable stages, separated only by relatively brief transition periods.

The Child as a Limited-Capacity Processing System

In trying to understand the differences in children's thinking at various ages, information-processing theorists draw comparisons between the information processing of computers and that of humans. A computer's information processing is limited by its hardware and by its software. The hardware limitations relate to both the computer's memory capacity and its efficiency in executing basic operations. The software limitations relate to the strategies and information that are available for particular tasks. People's thinking is limited by the same factors: memory capacity, efficiency of thought processes, and availability of useful strategies and knowledge. In the information-processing view, cognitive development arises from children's gradually surmounting their processing limitations through (1) expansion of the amount of information they can process at one time, (2) increasingly efficient execution of basic processes, and (3) acquisition of new strategies and knowledge.

The Child as Problem Solver

Also central to the view of human nature held by information-processing theories is the assumption that children are active problem solvers. As suggested by Klahr's analysis of his daughter's behavior, **problem solving** involves a goal, a perceived obstacle, and a strategy or rule for overcoming the obstacle and attaining the goal. A description of a younger child's problem solving reveals the same combination of goal, obstacle, and strategy:

> Georgie (a 2-year-old) wants to throw rocks out the kitchen window. The lawnmower is outside. Dad says that Georgie can't throw rocks out the window, because he'll break the lawnmower with the rocks. Georgie says, "I got an idea." He goes outside, brings in some green peaches that he had been playing with, and says: "They won't break the lawnmower."
>
> (Waters, 1989, p. 7)

In addition to illustrating the goal–obstacle–strategy sequence, this example highlights another basic tenet of information-processing approaches: Children's cognitive flexibility helps them pursue their goals. These goals may not always be ones that their parents would approve, but even young children show great ingenuity in surmounting the obstacles imposed by their parents, the physical environment, and their own processing and knowledge limitations.

Central Developmental Issues

Like all the theories described in this chapter, information-processing theories examine how *nature and nurture* work together to produce development. What makes information-processing theories unique is their emphasis on precise descriptions of *how change occurs.* The way in which information-processing theories address

problem solving the process of attaining a goal by using a strategy to overcome an obstacle the issues of nature and nurture and how change occurs can be seen particularly clearly in their accounts of the development of memory and problem solving.

The Development of Memory

Memory is central to everything we do. The skills we use on any task, the language we employ when writing or speaking, the emotions we feel on a given occasion—all of these depend on our memory of past experiences and the knowledge acquired through them. Indeed, without memory of our experiences, we would lose our very identity.

Components of the memory system In their attempt to understand the development of memory, information-processing theorists distinguish among three key memory structures: sensory memory, long-term memory, and working memory. **Sensory memory** refers to the fleeting retention of sights, sounds, and other sensations that have just been experienced. This information is briefly held in raw form until it either is identified and moved to working memory or is lost. Thus, if a child reads a sentence about a bird, the visual appearance of the letters *b-i-r-d* enters into sensory memory while the word is being identified. **Long-term memory** refers to information retained on an enduring basis, for example, the child's general knowledge about birds. **Working memory** (sometimes referred to as *short-term memory*) refers to a kind of workspace in which we gather, attend to, and actively process information from sensory memory and long-term memory. Thus, in the reading example, the meaning of "bird" would emerge as working memory integrates the sensory memory of the letters *b-i-r-d* on the page with knowledge about birds from long-term memory.

Information-processing theorists distinguish among these three memory structures because they differ in important ways, including the length of time they can retain information, how much information they can store, the neural mechanisms through which they operate, and their course of development. Sensory memory can hold a small-to-moderate amount of information for a fraction of a second. The brain areas that are called into play vary according to the sensory modality through which the information was obtained. Thus, the visual cortex would be especially active in sensory memory for sights, the auditory cortex would be especially active in sensory memory for sounds, and so on (Eichenbaum, 2003). The capacity of sensory memory is relatively constant over much of development, though it does increase somewhat (Cowan et al., 1999).

Working memory, like sensory memory, is limited in both capacity and duration. Depending on the task and the individual's abilities, age, and knowledge of the material, it can hold and operate on between 1 and 10 items (words, numbers, etc.) for periods ranging from a fraction of a second to about a minute (Smith & Jonides, 1998). Also like sensory memory, working memory comprises separate subsystems for storing information from different sensory modalities—a visual-spatial system for storing visual information, a verbal system for storing auditory information, and so on.

Correspondingly, the brain areas that are most active in working-memory processing vary with the type of information being processed and the type of processing being done. For retention of visual information, a network involving right-hemisphere areas of the frontal and parietal lobes seems to play a particularly active role; for retention of auditory information, corresponding areas in the left hemisphere tend to be particularly active.

sensory memory the fleeting retention of sights, sounds, and other sensations that have just been experienced

long-term memory information retained on an enduring basis

working (short-term) memory a kind of workspace in which information from sensory memory and long-term memory is brought together, attended to, and processed

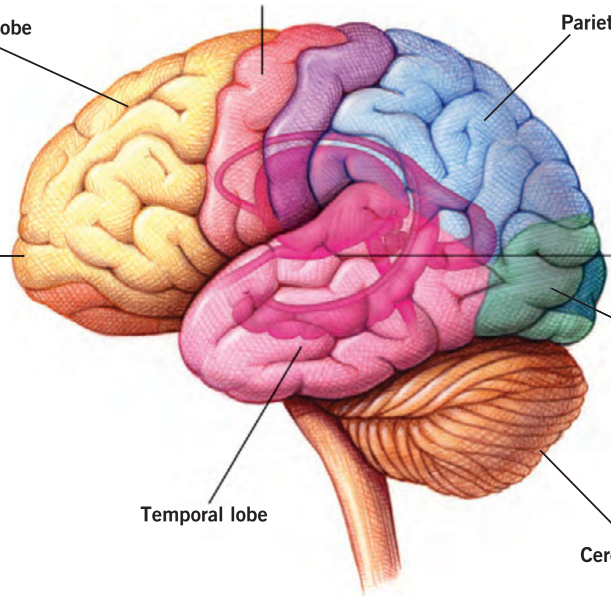

FIGURE 4.8 **The memory system is not located in any single brain area; instead, areas throughout the brain make major contributions to memory.**

Unlike sensory memory, however, working memory also includes an executive system for regulating attention, planning, and action. The prefrontal cortex plays an especially large role in such executive activities (Anderson, 2005; Nelson, Thomas, & de Haan, 2006). The basic organization of working-memory subsystems seems to be constant from early in childhood, but its capacity and speed of operation increase greatly over the course of childhood and adolescence (Gathercole, Pickering, Ambridge, & Wearing, 2004).

In contrast to the severe limits on the capacity and duration of sensory and working memory, long-term memory can retain an unlimited amount of information for unlimited periods of time. To cite one notable example, research shows that people who studied Spanish or algebra in high school often retain a substantial amount of what they learned in the subject 50 years later, despite both their not having used the information in the interim and their having accumulated vast stores of other skills, concepts, and knowledge in long-term memory over that period (Bahrick, 1994). Neural systems relevant to long-term retention are widely distributed throughout the cortex, with the area of the brain that is most active at any given time depending on the kind of information that is being processed. For example, the hippocampus and the temporal lobe of the cortex tend to be especially active in memory for facts about the world, whereas the motor cortex and cerebellum tend to be especially active in memory for actions (Nelson, Thomas, & de Haan, 2006; see Figure 4.8).

Explanations of memory development Information-processing theorists try to explain both the processes that make memory as good as it is at each age and the limitations that prevent it from being better. These efforts have focused on three types of capabilities: basic processes, strategies, and content knowledge.

BASIC PROCESSES The simplest and most frequently used mental activities are known as **basic processes.** They include *associating* events with each other, *recognizing* objects as familiar, *recalling* facts and procedures, and *generalizing* from one instance to another. Another basic process, which is key to all the others, is **encoding,** the

basic processes the simplest and most frequently used mental activities

encoding the process of representing in memory information that draws attention or is considered important

THE FAMILY CIRCUS **By Bil Keane**

"Mirror, mirror, on the wall, who's the fairest of the mall?"

Misencoding common sayings can lead to memorable confusions.

representation in memory of specific features of objects and events. With development, children execute basic processes more efficiently, which enhances their memory and learning for all kinds of materials.

Most of these basic processes are familiar, and their importance, obvious. However, encoding is probably less familiar. Appreciating its importance requires some understanding of the way in which memory works. People often think of memory as something akin to an unedited video recording of our experiences. Actually, memory is far more selective. People *encode* information that draws their attention or that they consider relevant, but they fail to encode a great deal of other information. Information that is not encoded is not remembered later. This failure is probably evident in your own memory of the American flag; although you have seen it many times, you most likely have not encoded how many red stripes and how many white stripes it has.

Studies of how children learn new balance-scale rules illustrate the importance of encoding for learning and memory. As discussed on page 137, most 5-year-olds predict that the side of the scale with more weight will go down, regardless of the distance of the weights from the fulcrum. Five-year-olds generally have difficulty learning more advanced balance-scale rules that take into account distance as well as weight, because they do not encode information about distance of the weights from the fulcrum. Teaching them to encode distance enables them to learn more advanced balance-scale rules that peers who were not taught to encode distance have trouble learning (Siegler, 1976; Siegler & Chen, 1998).

Like improved encoding, improved speed of processing plays a key role in the development of memory and learning. As shown in Figure 4.9, processing speed increases most rapidly at young ages but continues to increase through adolescence (Kail, 1991, 1997; Luna et al., 2004).

Two biological processes that contribute to faster processing are myelination and increased connectivity among brain regions (Luna et al., 2004). As discussed in Chapter 3, from the prenatal period through adolescence, increasing numbers of axons of neurons become covered with myelin, the fatty insulating substance that promotes faster and more reliable transmission of electrical impulses in the brain. Myelination seems to contribute to greater speed of processing not only by enhancing the efficiency of neural communication but also by enhancing the ability to resist distractions (Dempster & Corkill, 1999; Wilson & Kipp, 1998). Increasing connectivity among brain regions also increases processing capacity and speed by expanding the resources that can be marshaled for a given task and the efficiency of communication among brain areas. As noted in Chapter 3, such increased connectivity is especially prominent in later childhood and adolescence.

STRATEGIES Information-processing theories point to the acquisition and growth of strategies as another major source of the development of memory and learning. A number of these strategies emerge between ages 5 and 8 years, among them the strategy of **rehearsal,** the repeating of information over and over in order to remember it. The following newspaper item illustrates the usefulness of rehearsal for remembering information verbatim:

> A 9-year-old boy memorized the license plate number of a getaway car following an armed robbery, a court was told Monday. . . . The boy and his friend . . . looked in the drug store window and saw a man grab a 14-year-old cashier's neck. . . . After the robbery, the boys mentally repeated the license number until they gave it to police.
>
> (*Edmonton Journal,* Jan. 13, 1981, cited in Kail, 1984)

rehearsal the process of repeating information over and over to aid memory of it

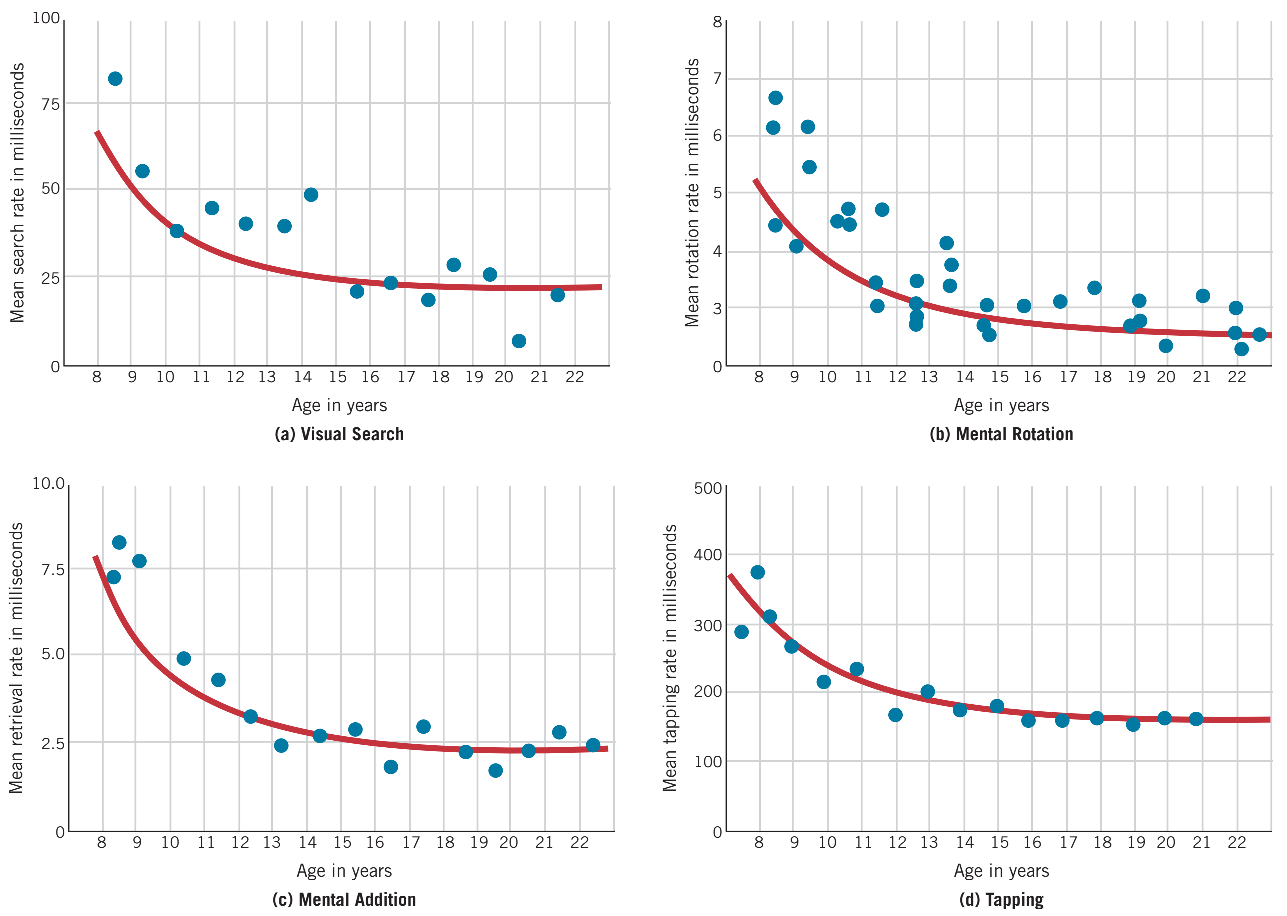

FIGURE 4.9 Increase with age in speed of processing on four tasks Note that on all four tasks, the increase is rapid in the early years and more gradual later. (Data from Kail, 1991)

Had the boys witnessed the same event when they were 5-year-olds, they probably would not have rehearsed the numbers and would have forgotten the license number before the police arrived.

Another widely used memory strategy that becomes increasingly prevalent during the early school years is **selective attention,** the process of intentionally focusing on the information that is most relevant to the current goal. If 7- and 8-year-olds are shown objects from two different categories (e.g., several toy animals and several household items) and are told that they later will need to remember the objects in only one category (e.g., "You'll need to remember the animals"), they focus their attention on the objects in the specified category and remember more of them. In contrast, given the same instructions, 4-year-olds pay roughly equal attention to the objects in both categories, which reduces their memory for the objects they need to remember (DeMarie-Dreblow & Miller, 1988).

CONTENT KNOWLEDGE Information-processing theories also point to a third explanation of development of memory and learning: improved content knowledge. With age and experience, children's knowledge about almost everything increases. Their greater knowledge improves recall of new material by making it easier to integrate the new material with existing understanding (Pressley & Hilden, 2006).

selective attention the process of intentionally focusing on the information that is most relevant to the current goal

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Through repeated visits to doctors' offices and through other experiences that occur in more or less fixed sequences, children form memories that let them know what to expect in similar future situations.

The importance of content knowledge to memory is illustrated by the fact that when children know more about a topic than adults do, their memory for new information about the topic often is better than that of the adults. For example, when children and adults are provided new information about children's TV programs and books, the children generally remember more of the information than do the adults (Lindberg, 1980, 1991). Similarly, children who know a lot about soccer learn more from reading new soccer stories than do other children who are both older and have higher IQs but who know less about soccer (Schneider, Korkel, & Weinert, 1989).

Prior content knowledge improves memory for new information in several different ways. One is by improving encoding. In tests of memory of various positionings of chess pieces on a board, child chess experts remember far more than do adult novices because the experts' greater knowledge leads to their encoding higher-level chunks of information that include the positions of several pieces relative to each other rather than encoding the location of each piece separately (Chi & Ceci, 1987). Content knowledge also improves memory by providing useful associations. A child who is knowledgeable about birds knows that type of beak and type of diet are associated, so remembering either one increases memory for the other (Johnson & Mervis, 1994). In addition, content knowledge indicates what is and is not possible and therefore guides memory in useful directions. For example, when people familiar with baseball are asked to recall a particular inning of a game that they watched and they can remember only two outs in that inning, they recognize that there must have been a third out and search their memories for it, whereas people who lack baseball knowledge do not (Spilich et al., 1979).

The Development of Problem Solving

As noted earlier, information-processing theories depict children as active problem solvers whose use of strategies often allows them to overcome limitations of knowledge and processing capacity. In this section, we present an information-processing perspective on the development of problem solving in general—the overlapping-waves approach—and also examine two particularly important problem-solving processes: planning and analogical reasoning.

The overlapping-waves approach Piaget's theory depicted children of a given age as using a particular strategy to solve a particular class of problems. For example, he described 5-year-olds as solving conservation-of-number problems (Figure 4.6) by choosing the longer row of objects, and 7-year-olds as solving the same problems by reasoning that if nothing was added or subtracted, the number of objects must remain the same. According to **overlapping-waves theory,** however, children actually use a variety of approaches to solve this and other problems (Siegler, 1996). For example, examining 5-year-olds' reasoning on repeated trials of the conservation-of-number problem reveals that most children use at least three different strategies (Siegler, 1995). The same child who on one trial incorrectly reasons that the longer row must have more objects will on other trials correctly reason that just spreading a row does not change the number of objects, and on yet other trials will count the number of objects in the two rows to see which has more.

Figure 4.10 presents the typical pattern of development envisioned by the overlapping-waves approach, with strategy 1 representing the simplest strategy, and strategy 5, the most advanced. At the youngest age depicted, children usually use

overlapping-waves theories an information-processing approach that emphasizes the variability of children's thinking strategy 1, but they sometimes use strategy 2 or 4. With age and experience, the strategies that produce more successful performance become more prevalent; new strategies also are generated and, if they are more effective than previous approaches, are used increasingly. Thus, by the middle of the age range in Figure 4.10, children have added strategies 3 and 5 to the original group and have almost stopped using strategy 1.

This model has been shown to accurately characterize children's problem solving in a wide range of contexts. Among the areas in which individual children have demonstrated the use of several strategies for solving a given problem are arithmetic, time-telling, reading, spelling, scientific experimentation, biological understanding, descent of ramps, recall from memory, and understanding of false beliefs (see pages 269–270) (Amsterlaw & Wellman, 2004; Kuhn & Franklin, 2006; Lee & Karmiloff-Smith, 2002; Miller & Coyle, 2000; Siegler, 2006). For example, in descending relatively steep ramps, an individual toddler will sometimes crawl, sometimes slide on her belly, sometimes slide on her behind, sometimes slide head first, sometimes slide feet first, sometimes inch along in a sitting position, and sometimes refuse to go down at all (Adolph, 1997).

Such strategic variability allows children to adjust to the varying challenges that life presents. In the case of ramp descent, for example, 1-year-olds usually crawl or walk down ramps that are not inclined enough to pose the risk of a fall, slide down somewhat steeper ramps on their bellies or behinds, and refuse to descend very steep ramps in any manner. Consistent with the view that variable strategy use is adaptive, the more strategies children know, the better their problem solving and learning tend to be (Goldin-Meadow & Alibali, 2002; Kuhn & Franklin, 2006). (Box 4.2 illustrates how this focus on strategic development can improve education.)

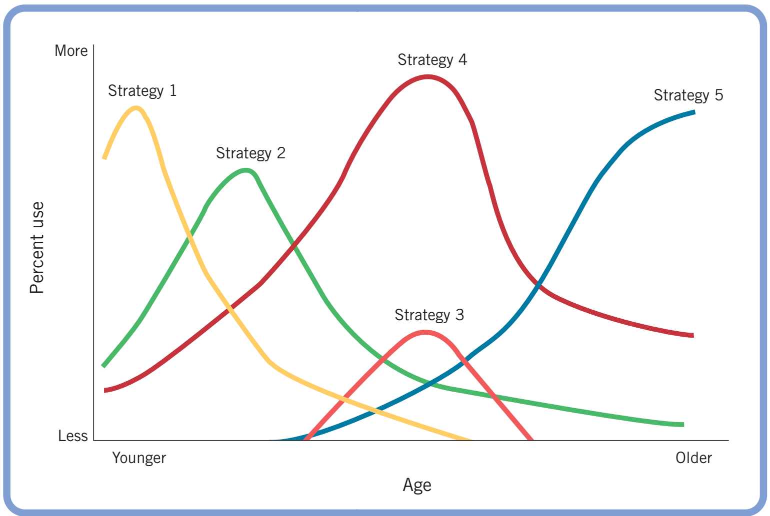
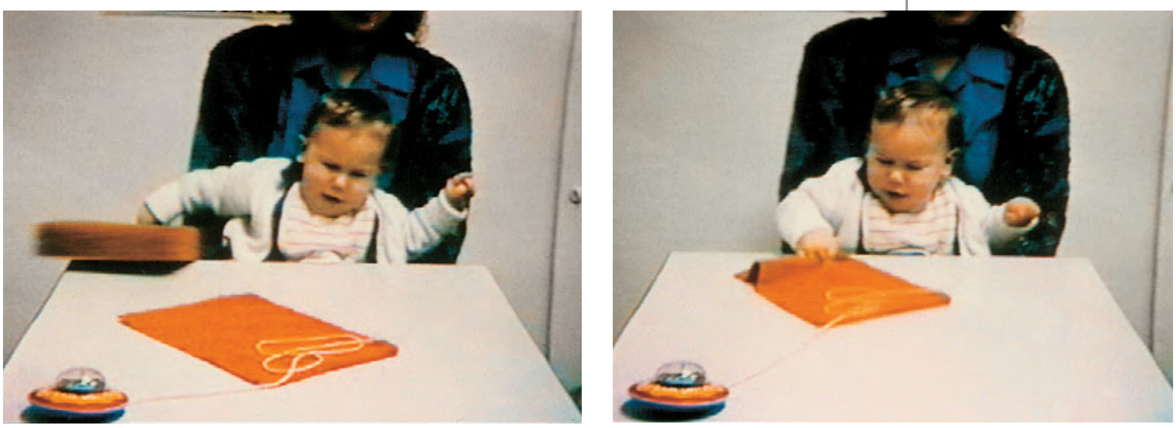


FIGURE 4.10 The overlapping-waves model The overlapping-waves model proposes that, at any one age, children use multiple strategies; that with age and experience, they rely increasingly on more advanced strategies (the ones with the higher numbers); and that development involves changes in use of existing strategies as well as discovery of new approaches.

Planning Early in development, children learn an important fact about problem solving: they often are more successful if they plan before acting. Children begin to form simple plans by their 1st birthday. In one demonstration of this capability, Willatts (1990) presented 12-month-olds with a solid barrier, behind which lay a cloth with a string attached and a toy that was too far away for the baby to reach (Figure 4.11). Sometimes the toy was attached to the string; other times it



COURTESY OF PETER WILLATTS, UNIVERSITY OF DUNDEE, SCOTLAND

FIGURE 4.11 Planning Procedure used by Willatts (1990) to examine 12-month-olds' planning. To get the attractive toy, the baby needed to knock the barrier out of the way (left frame) and then pull in the towel connected by the string to the toy (right frame).

applications 4.2

Educational Applications of Information-Processing Theories

Children's knowledge of numbers when they begin kindergarten predicts their mathematics achievement years later—in elementary school, middle school, and even high school (Duncan et al., 2007; Stevenson & Newman, 1986). It is especially unfortunate, then, that kindergartners from low-income families lag far behind middle-income peers in counting, number recognition, arithmetic, and knowledge of numerical magnitudes (e.g., understanding that 7 is less than 9 and that both are closer to 10 than to 0 on a number line).

What might account for these early differences in numerical knowledge of children from different economic backgrounds? An information-processing analysis suggested that numerical experience, in particular experience playing numerical board games like Chutes and Ladders, might be important. In Chutes and Ladders, players must move a token across 100 consecutively numbered squares, advancing on each turn by the number of spaces determined by a spinner. The higher the number of the square on which a child's token rests at any given point in the game, the greater the number of number names the child is likely to have spoken and heard, the greater the distance the child has moved the token, the greater the time the child has been playing the game, and the greater the number of discrete moves the child has made with the token. These verbal, spatial, temporal, and kinesthetic cues provide a broadly based, multisensory foundation for knowledge of numerical magnitudes, a type of knowledge that is closely related to mathematics achievement test scores (Booth & Siegler, 2006; 2008).

Ramani and Siegler (2008) applied this information-processing analysis to improving the numerical understanding of low-income preschoolers. The researchers randomly assigned 4- and 5-year-olds from low-income families to either an experimental number-board condition or a control color-board condition. The number-board condition was virtually identical to the first row of the Chutes and Ladders board; it included 10 squares numbered consecutively from left to right. On each turn, the child spun a spinner that yielded a "1" or a "2" and moved his or her token the corresponding number of squares on the board, stating the number on each square in the process. For example, if a player's token was on the square with the "4," and the player spun a "2," the player would say, "5, 6" while moving the token from the "4" to the "6." Children in the color-board condition played the same game, except that their board had no numbers and the players would say the name of the color of each square as they advanced their token. Children in both conditions were given a pretest that examined their knowledge of numbers before playing the game, and then played the game for four 15-minute sessions over a two-week period. At the end of the fourth session, the children were given a posttest on their knowledge of numbers; nine weeks later, they were given a follow-up test identical to the pretest and posttest.

On the posttest, children who played the number-board game showed improved knowledge of the numbers 1 through 10 on all four number tasks that were presented—counting, reading of numbers, magnitude comparisons, and estimates of the locations of numbers on a number line. Significantly, all the gains were maintained on the follow-up test nine weeks later. In contrast, children who played the color-board game showed no improvement in any aspect of number knowledge. Moreover, children's reports of how often they played Chutes and Ladders and other board games at home was positively correlated with their initial knowledge on all four numerical tasks, and middle-income children reported playing numerical board games (though not video games) much more often than children from low-income backgrounds.

A subsequent study (Siegler & Ramani, 2009) demonstrated that playing the 1–10 board game also improves preschoolers' ability to learn the answers to arithmetic problems. Taken together, this evidence suggests that numerical board games represent a quick, effective, and inexpensive means of improving the numerical knowledge of low-income children before they begin formal education.

was not. The babies were quicker to try to get the toy when it was attached to the string than when it was not. Willatts's analysis of the children's information processing indicated that they had formulated a three-step plan for reaching the goal: remove the obstacle, pull in the cloth, and grab the string to get the toy.

As children grow older, they make plans for a wide variety of situations and problems, such as how to get to friends' houses, what books to read for reports, when to study for tests, and how to get their way with parents. This planning helps them solve a broader range of problems than they would be able to solve without planning (Hudson, Sosa, & Schapiro, 1997).

Despite the advantages of planning, many young children fail to plan in situations in which it would help their problem solving (Berg et al., 1997). The question is why. Information-processing analyses suggest that one reason why planning is difficult for young children is that it requires inhibiting the desire to solve the problem immediately in favor of first trying to construct the best strategy. As suggested by the challenge that games such as "Simon Says" and "Mother May I" represent for preschoolers, children below age 5 or 6 years tend to have special difficulty inhibiting the desire to act (Dempster, 1995; Diamond, Kirkham, & Amso, 2002), a tendency that is even greater in young children with learning problems (Winsler et al., 1999). This difficulty in inhibiting action is largely due to the fact that the frontal lobe, which plays an important part in inhibition, is one of the last parts of the brain to mature, with substantial maturation occurring between age 5 and adolescence (Diamond & Amso, 2008).

A second reason why planning is difficult for young children is that they tend to be overly optimistic about their abilities and think that they can solve problems more effectively than they are actually able to (Bjorklund, 1997; Schneider, 1998). This overconfidence can lead them to not plan, because they think they will succeed without doing so. Their overoptimism also can lead young children to act rashly. For example, 6-year-olds who overestimate their physical abilities have more accidents than do children who evaluate their abilities more realistically (Plumert, 1995). Even 12-year-olds leave less distance between themselves and oncoming vehicles when crossing streets than do adults (Plumert, Kearney, & Cremer, 2004). As these examples imply, brain maturation and experiences that reduce overoptimism and demonstrate the value of planning lead to increases in the frequency and quality of planning that continue into adolescence and beyond (Chalmers & Lawrence, 1993).

PHOTOS COURTESY OF JODIE PLUMERT

Young children's overoptimism sometimes leads them to engage in dangerous activities. This particular plan worked out fine, but not all do.

Analogical reasoning People often understand new problems by drawing analogies to familiar ones. For example, Goswami (2001) found that reminding 3- and 4-year-olds of the story "Goldilocks and the Three Bears" helped them solve analogous problems in which they needed to rank objects on dimensions such as temperature (boiling hot, hot, and warm food). Information-processing analyses indicate that, as in this example, successful analogical reasoning requires ignoring superficial dissimilarities (whether the objects are bears or food) and focusing on underlying parallel relations (the ordering from greatest to least).

As with planning, a rudimentary form of analogical reasoning emerges around a child's 1st birthday. This early competence, however, is initially limited to situations in which the new problem closely resembles the old. Thus, when 10-month-olds saw their mothers demonstrate how to solve the barrier-and-toy problem shown in Figure 4.11, they applied the lesson to new parallel problems only when the new problems duplicated the old in several superficial ways—such as the colors, sizes, shapes, and locations of objects (Chen, Sanchez, & Campbell, 1997).

Superficial similarity between the original and new problems continues to influence analogical reasoning well beyond infancy. Even in middle childhood, younger children often require more surface similarity to draw an analogy than do older ones (Gentner & Markman, 1997). When asked to explain the statement "A camera is like a tape recorder," for example, 6-year-olds tend to cite superficial similarities, such as that both are often black; in contrast, 9-year-olds tend to cite deeper similarities, such as that both devices are used to record information (Gentner et al., 1995). The 9-year-olds' deeper understanding of the nature of tape recorders and cameras enables them to see analogies between the two devices that the less knowledgeable 6-year-olds miss.

review: Information-processing theories envision children as active learners and problem solvers who continuously devise means for overcoming their processing limits and reaching their goals. Sensory memory, working memory, and long-term memory are key structures, whose capacity and processing speed influence all information processing. Planning and analogical reasoning are among the cognitive activities that information-processing theories envision as contributing most to the development of problem solving. Cognitive growth in general, and development of memory and learning in particular, are seen as involving increasingly efficient execution of basic operations, construction of more effective strategies, and acquisition of new content knowledge.

Core-Knowledge Theories

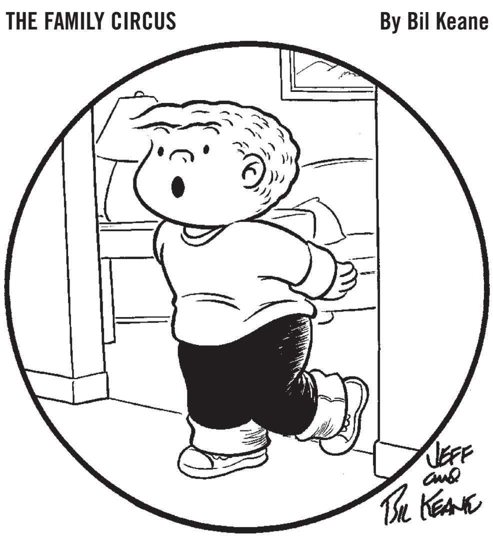
I didn't break the lamp, and I won't do it again.

—3-year-old, speaking to her mother (cited in Vasek, 1986)

Although transparent from an adult's perspective, this 3-year-old girl's attempted cover-up reflects surprisingly sophisticated reasoning. She realizes that her mother does not know all that she herself knows about how the lamp was broken, so she attempts to deny responsibility. At the same time, she knows that her mother may not believe her, so she hedges her bets. The girl's skill at deception is typical for her age. When more than 50 3-year-olds were encouraged by an experimenter to deceive another adult as to the whereabouts of a "treasure" the children had seen a doll hide, the majority destroyed clues to the treasure's location that the doll had "accidentally" left on the scene and lied when asked about where the treasure was hidden (Chandler, Fritz, & Hala, 1989).

Such studies of deception illustrate two characteristic features of research inspired by **core-knowledge theories.** One is that the research focuses on areas—such as understanding of other people's goals and intentions—that have been important throughout human evolutionary history. Other key areas similarly viewed as core knowledge include recognizing the difference between living and nonliving things, identifying human faces, finding one's way around the environment, and learning language.

A second feature of the core-knowledge approach that is reflected in deception studies is the assumption that in certain areas of probable importance in human evolution, young children reason in ways that are considerably more advanced than Piaget suggested were possible. If children under the age of 6 or 7 were completely egocentric, they would assume that other people's knowledge is the same as their own, in which case, there would be no point to making a false statement, because the other person would know it was false. In fact, as we will see, deception studies like the one described above indicate that children as young as 3 years old not only can understand that other people can be fooled but also act on that understanding. The question is how children come to have such sophisticated knowledge so early in life.



"Mommy, how much grape juice would be bad for the rug?"

Indirect ways of breaking bad news are a specialty of young children and reflect their understanding that other people's reactions might not be the same as their own.

core-knowledge theories approaches that emphasize the sophistication of infants' and young children's thinking in areas that have been important throughout human evolutionary history

View of Children's Nature

Core-knowledge theories depict children as active learners. As discussed above, for example, research from the core-knowledge perspective shows that 3-year-olds understand deception much better when they are actively involved in perpetrating the deceit than when they merely witness the same deception being perpetrated by others (Carlson, Moses, & Hix, 1998; Sullivan & Winner, 1993). In this respect, the core-knowledge perspective on children's nature resembles that of Piagetian and information-processing theories.

The way in which core-knowledge theories differ most dramatically from Piagetian and information-processing theories is in their view of children's innate capabilities. Piaget and most information-processing theorists believe that children enter the world equipped with only general learning abilities and that they must actively apply these abilities to gradually increase their understanding of all types of content. In contrast, core-knowledge theorists view children as entering the world equipped not only with general learning abilities but also with specialized learning mechanisms, or mental structures, that allow them to quickly and effortlessly acquire information of evolutionary importance. Where the central metaphors within Piagetian and information-processing theories are, respectively, the child as scientist and the child as computational system, the central metaphor in the core-knowledge approach is the child as well-adapted product of evolution. This metaphor is strikingly apparent in the following statement:

> The brain is no less a product of natural selection than the rest of the body's structures and functions. . . . Hearts evolved to support the process of blood circulation, livers evolved to carry out the process of toxin extraction, and mental structures evolved to enable the learning of certain types of information necessary for adaptive behavior.
>
> (Gelman & Williams, 1998, p. 600)

Research on infants' face perception supports the view that people possess specialized learning mechanisms for acquiring information important to survival. From birth onward, brain structures outside the cortex, in particular the superior colliculus, bias infants to prefer looking at faces over other objects (de Haan, Johnson, & Halit, 2003). If infants were not biased to look at faces, they probably would take much longer to learn to recognize their parents and others on whom their survival depends.

Core-knowledge theorists, in particular the noted linguist Noam Chomsky (1988), have proposed that children also have specialized language-learning mechanisms that allow them to rapidly master the complicated systems of grammatical rules that are present in all human languages. One type of evidence for such mechanisms is the universality of language acquisition. Virtually all children in all societies master the basic grammar of their native language quickly and effortlessly, even though adults almost never directly instruct them. In contrast, understanding other complex rule systems—such as those in geometry, logic, and kinship relations (e.g., second cousin, twice removed)—is not universal and requires direct instruction from adults and considerable effort from children.

Another reason for believing that children possess mechanisms that are specialized for learning language is that certain areas in the middle of the left hemisphere of the brain are consistently active in processing grammar. Any damage to those left-hemisphere areas harms grammatical competence to a much greater extent than does similar damage to the corresponding areas of the brain's right hemisphere. The behavioral and physiological data together provide good reason to believe that people possess specialized mechanisms for learning language. Thus, whereas Piaget and information-processing theorists depict intelligence as a unified whole that generates understanding of all domains, core-knowledge theorists depict intelligence as a mixture of general learning abilities and powerful specialized abilities that help children learn to solve evolutionarily important problems, that is, problems that have been important for survival throughout human existence.

Central Developmental Issues

Like Piaget and information-processing theorists, core-knowledge theorists believe that development is produced by the interaction of nature and nurture. Unlike most theorists who take those approaches, however, core-knowledge theorists believe that children's nature includes either an innate understanding of crucial concepts or specialized learning abilities that allow them to form the concepts quickly and effortlessly.

Domain Specificity

The basic understandings proposed by core-knowledge theorists are assumed to be **domain specific,** that is, limited to a particular area, such as living things or inanimate objects. Domain-specific understandings in these areas allow infants to distinguish between living and nonliving things; to anticipate that nonliving physical objects they encounter for the first time will remain stationary unless an external force is applied to them; to anticipate that animals they encounter for the first time might well move on their own; and to learn quickly in these and other areas of probable evolutionary importance. Core-knowledge theorists also have emphasized children's early understanding of other central domains including language, space, number, and people. This research will play an important role in the next three chapters.

Children's Informal Theories

A number of core-knowledge theorists have proposed that young children actively organize their understanding of the most important domains into informal theories (Carey, 1985; Gelman, 2003). In particular, they maintain that children form naive theories of *physics* (knowledge of objects), *psychology* (knowledge of people), and *biology* (knowledge of plants and animals). As rudimentary and informal as these theories may be, they share three important characteristics with formal scientific theories:

1. They identify fundamental units for dividing up all objects and events into a few basic categories.
2. They explain many phenomena in terms of a few fundamental principles.
3. They explain events in terms of unobservable causes.

Each of these characteristics is evident in preschoolers' understanding of biology (Evans, 2008; Gelman, 2003; Inagaki & Hatano, 2008). Consistent with the first characteristic, preschoolers divide all objects into people, other animals, plants, and nonliving things. Consistent with the second characteristic, preschoolers understand broadly applicable principles, such as that a desire for food and water underlies many behaviors of animals. Consistent with the third characteristic, preschoolers know that vital activities of animals, such as reproduction and movement, are caused by something inside the animals themselves, as opposed to the external forces that determine the behavior of objects.

domain specific limited to a particular area, such as living things or people

Why would children form intuitive theories of physics, biology, and psychology? According to core-knowledge theorists Henry Wellman and Susan Gelman (1998), the reason probably lies in our evolutionary past. Children have always needed to know about physical objects in order to perceive the environment accurately and to move around in it safely. They have needed to know about animals and plants to avoid predators and poisons. They have needed to understand other people in order to communicate their wants and needs and to pursue shared goals. Again, the core-knowledge metaphor of the child as a well-equipped product of evolution is clear.

When do children first possess such core theories? Spelke (e.g., 2003) speculates that infants begin life with a primitive theory of physics, that is, of inanimate objects. This theory includes the knowledge that the world contains physical objects that occupy space, move only in response to external forces, move in continuous ways through space rather than jumping from one position to another, and cannot simultaneously occupy the same space as another object. One source of evidence for this view is Baillargeon's (1987, 1994) finding that 3-month-olds show surprise when, thanks to a clever research arrangement of mirrors, a solid object appears to move through the space occupied by another solid object.

Wellman and Gelman (1998) suggested that the first theory of psychology may emerge at around 18 months of age, and the first theory of biology at around 3 years. The first theory of psychology is organized around the understanding that other people's actions, not just one's own, reflect their goals and desires. For example, 2-year-olds realize that another person will want to eat if he or she is hungry, regardless of whether they themselves are. The first theory of biology is organized around the realization that people and other animals are living things, different from nonliving things and plants. For example, 3- and 4-year-olds realize that animals, but not manufactured objects, move on the basis of their own power (Gelman, 2003).

The joy that animals bring children may provide part of the motivation for the children's informal theories of living things.

Of course, a huge amount of development occurs beyond these initial theories. Some of the development involves building on the original organization and filling in details. For example, even 3-month-olds understand that an object (e.g., a glass) will fall unless at least some of it is supported by another object (e.g., a table), but not until about 7 months of age do infants understand that the object also will fall if only a small portion of it is supported (Baillargeon, 1994). In other cases, children may replace rudimentary theories with more advanced ones. Children's initial biological theory distinguishes animals from inanimate objects and plants; not until the age of 7 years are children convinced that the category of living things includes plants as well as animals (Inagaki & Hatano, 2008).

Due to the many fascinating discoveries that core knowledge has yielded about children's earliest understandings, and due to the light that this research has shed on human nature, core-knowledge theories have become increasingly popular in recent years. This research is examined in greater depth in Chapter 7. We close this section's overview by examining educational implications of the core-knowledge approach (Box 4.3).

applications 4.3

Educational Applications of Core-Knowledge Theories

Operating from the principle that people's existing knowledge greatly influences their learning, Hatano and Inagaki (1996) noted several implications of findings regarding children's naive theories of biology that could be used to help children gain a more advanced understanding of the subject. One such implication is that by the time children enter kindergarten, their theory of unobservable causes—such as those related to animals' vital activities—can be built upon to teach them concepts that are usually thought to be beyond their grasp. For example, they can understand that invisible germs cause diseases and that invisible genes cause resemblances between parents and children (Kalish, 1996; Springer, 1996).

A second instructional implication derives from a more specific finding: children's early theories of biology are influenced by their knowledge about human beings. Young children extrapolate from what they know about people to predict the qualities of other animals, a process known as **personification** (Carey, 1985; Inagaki & Hatano, 2008). Although personification leads to many valid conclusions, it also interferes with understanding of some biological concepts. For example, it makes it difficult for children to understand that plants are alive, because plants clearly do not form intentions and pursue goals in the same sense as people do. Instructional programs that emphasize that plants actually do move in ways that help them function—for example, stems' moving toward sunlight and roots' moving toward water—can help young children overcome such misconceptions (Opfer & Siegler, 2004).

review: Core-knowledge theorists envision children as well-equipped products of evolution. Such theories focus on development of understanding in domains of likely evolutionary importance, such as space, time, language, biology, and so on. Researchers who take this approach have demonstrated that infants and young children possess surprising understanding of these domains. Core-knowledge theorists believe that this early competence is made possible by innate, domain-specific understanding and specialized learning mechanisms. Children are viewed as active thinkers who form theories that divide objects and events into a few basic categories, reflect certain fundamental principles, and explain events in terms of unobservable causes.

Sociocultural Theories

A mother and her 4-year-old daughter, Sadie, assemble a toy, using a diagram to guide them:

> *Mother:* Now you need another one like this on the other side. Mmmmm . . . there you go, just like that.
> *Sadie:* Then I need this one to go like this? Hold on, hold on. Let it go. There. Get that out. Oops.
> *M:* I'll hold it while you turn it. *(Watches Sadie work on toy)* Now you make the end.
> *S:* This one?
> *M:* No, look at the picture. Right here *(points to diagram)*. That piece.
> *S:* Like this?
> *M:* Yeah.
>
> (Gauvain, 2001, p. 32)

This interaction probably strikes you as completely unexceptional—and it is. From the perspective of **sociocultural theories,** however, it and thousands of other everyday interactions like it are of the utmost importance, because they are the mechanisms that move development forward.

One noteworthy characteristic of the event, from the sociocultural perspective, is that Sadie is learning to assemble the toy in an interpersonal context.

personification generalizing knowledge about people to infer properties of other animals

sociocultural theories approaches that emphasize that other people and the surrounding culture contribute to children's development

Sociocultural theorists emphasize that much of development takes place through direct interactions between children and other people—parents, siblings, teachers, playmates, and so on—who want to help children acquire the skills and knowledge valued by their culture. Thus, whereas Piagetian, information-processing, and core-knowledge theories emphasize children's own efforts to understand the world, sociocultural theories emphasize the developmental importance of children's interactions with other people.

The interaction between Sadie and her mother is also noteworthy because it exemplifies **guided participation,** a process in which more knowledgeable individuals organize activities in ways that allow less knowledgeable people to engage in them at a higher level than they could manage on their own (Rogoff, 2003). Sadie's mother, for example, holds one part of the toy so that Sadie can screw in another part. On her own, Sadie would be unable to screw the two parts together and therefore could not improve her skill at the task. Similarly, Sadie's mother points to the relevant part of the diagram, enabling Sadie to decide what to do next and also to learn how diagrams convey information. As this episode illustrates, guided participation often occurs in situations in which the explicit purpose is to achieve a practical goal, such as assembling a toy, but in which learning occurs as a by-product of the activity.

Through guided participation, parents can help children not only accomplish immediate goals but also learn skills, such as how to use written instructions and diagrams to assemble objects.

A third noteworthy characteristic of the interaction between Sadie and her mother is that it occurs in a broader cultural context. This context includes not only other people but also the innumerable products of human ingenuity that sociocultural theorists refer to as **cultural tools:** symbol systems, artifacts, skills, values, and so on. In the example of Sadie and her mother, the relevant symbol systems include the language they use to convey their thoughts and the diagram they use to guide their assembly efforts; the relevant artifacts include the toy and the printed sheet on which the diagram appears; the relevant skills include the proficiency in language that allows them to communicate with each other and the procedures they use to interpret the diagram; and the values include the culture's approval of parents interacting with their children in the way that Sadie's mother does and of young girls' learning mechanical skills. In the background are broader technological, economic, and historical factors. Indeed, the interaction itself would not be occurring were it not for the technology needed to manufacture toys and print diagrams, an economy that allows parents the leisure for such interactions, and a history leading up to the symbol systems, artifacts, skills, and values reflected in the interaction. Thus, sociocultural theories can help us appreciate the many aspects of culture embodied in even the smallest everyday interactions.

View of Children's Nature

The giant of the sociocultural approach to cognitive development, and in many ways its originator, was the Russian psychologist Lev Semyonovich Vygotsky. Although Vygotsky and Piaget were contemporaries, much of Vygotsky's most important work was largely unknown outside the Soviet Union until the 1970s. Its appearance created a stir, in part because Vygotsky's view of children's nature was so different from Piaget's.

guided participation a process in which more knowledgeable individuals organize activities in ways that allow less knowledgeable people to learn

cultural tools the innumerable products of human ingenuity that enhance thinking

DAVIDSON FILMS, INC.

The Russian psychologist Lev Vygotsky, the founder of the sociocultural approach to child development.

private speech the second phase of Vygotsky's internalization-of-thought process, in which children develop their self-regulation and problem-solving abilities by telling themselves aloud what to do, much as their parents did in the first stage

Vygotsky's Theory

As noted earlier, Piaget depicted children as little scientists, trying to understand the world on their own. Vygotsky, in contrast, portrayed them as social beings, intertwined with other people who are eager to help them gain skills and understanding. Where Piaget viewed children as intent on mastering physical, mathematical, and logical concepts that are the same in all times and places, Vygotsky viewed them as intent on participating in activities that happen to be prevalent in their local setting. Where Piaget emphasized qualitative changes in thinking, Vygotsky emphasized continuous, quantitative changes. These Vygotskyian views gave rise to the central metaphor of sociocultural theories: children as social beings, shaped by, and shaping, their cultural contexts.

Vygotsky's emphasis on children as social beings is evident in his perspective on the relation between language and thought. Whereas Piaget viewed the two as largely unrelated, Vygotsky (1934–1962) viewed them as integrally related; in particular, he believed that thought is internalized speech and that thought originates in large part in statements that parents and other adults make to children.

To illustrate the process of internalizing speech, Vygotsky described three phases of its role in the development of children's ability to regulate their own behavior and problem solving. At first, children's behavior is controlled by other people's statements (as in the example of Sadie and her mother assembling the toy); then, children's behavior is controlled by their own **private speech,** in which they tell themselves aloud what to do, much as their parents might have earlier; and then their behavior is controlled by internalized private speech (thought), in which they silently tell themselves what to do. The transition between the second and third phases often involves whispers or silent lip movements; in Vygotsky's terms, the speech "goes underground" and becomes thought. Private speech is most prevalent between ages 4 and 6 years, although older children and adults also use it on challenging tasks, such as assembling model airplanes or following complex directions (Winsler et al., 2003). In addition, the progression from external to internalized speech emerges not only with age but also with experience; children generate a considerable amount of overt private speech when they first encounter a challenging task, but the amount lessens as they master it (Berk, 1994).

A Mayan mother teaches her daughter weaving skills by involving her in the process. The inclination to teach and the ability to learn from teaching are among the most distinctly human characteristics.

BOB DAEMMRICH / STOCK BOSTON

Children as Teachers and Learners

Contemporary sociocultural theorists, such as Michael Tomasello (2001), have extended Vygotsky's insights. Tomasello proposed that the human species has two unique characteristics that are crucial to the ability to create complex, rapidly changing cultures. One of these is the inclination to teach others of the species; the other is the inclination to attend to and learn from such teaching. In every human society, adults communicate facts, skills, values, and traditions to their young. This is what makes culture possible; as Isaac Newton noted, it enables the new generation to stand on the shoulders of the old and thus to see farther. The inclination to teach emerges very early: all normal 2-year-olds spontaneously point to objects to call other people's attention to what they themselves find interesting. Only humans engage in such rudimentary teaching behaviors that are not directly tied to survival. This inclination to teach and to learn from teaching is what enables children to be socialized into their culture and to pass that culture on to others.

Children as Products of Their Culture

Sociocultural theorists believe that many of the *processes* that produce development, such as guided participation, are the same in all societies. However, the *content* that children learn—the particular symbol systems, artifacts, skills, and values—vary greatly from culture to culture and shape thinking accordingly.

One example of the impact of culturally specific content comes from a study of long-term analogical reasoning (Chen, Mo, & Honomichi, 2004). American and Chinese college students were asked to solve two problems. One problem required a solution akin to the strategy of leaving a trail of bright stones in "Hansel and Gretel," a tale well known to the American students but unknown to the Chinese. The American students were far more successful in solving that problem, and many of them alluded to the fairy tale even though they had not heard it in many years. The other problem required a solution analogous to a fairy tale that was well known to the Chinese students but unknown to the Americans. In this case, the Chinese students were vastly superior in solving that problem, and many alluded to the relevant fairy tale.

Children's memories of their own experiences also reflect their culture. When 4- to 8-year-olds from China and the United States were asked to describe their earliest memories, their descriptions differed in ways that reflected their culture's attitudes and values (Wang, 2007). Chinese culture prizes and promotes interdependence among people, especially among close relatives. European-American culture, in contrast, prizes and promotes the independence of individuals. Consistent with these cultural emphases, the Chinese children's reports included more references to other people, whereas those of the American children included more references to the child's own feelings and reactions. Thus, the attitudes and values of a culture, as well as its artifacts and technologies, shape the thoughts and memories of people in that culture.

ARIEL SKELLEY / CORBIS STOCK MARKET

As illustrated by this photo of an East Asian father teaching his children to use an abacus, the tools available in a culture shape the learning of children within that culture.

Central Developmental Issues

Vygotsky and contemporary sociocultural theorists have proposed a number of specific ideas about *how change occurs* through social interaction. One of these ideas—guided participation—has already been discussed. In this section, we examine two related concepts that play prominent roles in sociocultural analyses of change: intersubjectivity and social scaffolding.

Intersubjectivity

Sociocultural theorists believe that the foundation of human cognitive development is our ability to establish **intersubjectivity,** the mutual understanding that people share during communication (Gauvain, 2001; Rommetveit, 1985). The idea behind this imposing term is both simple and profound: effective communication requires participants to focus on the same topic, and also on each other's reaction to whatever is being communicated. Such a "meeting of the minds" is indispensable for effective teaching and learning.

intersubjectivity the mutual understanding that people share during communication

LAURA DWIGHT

Joint attention, the process through which social partners focus on the same external object, underlies the human capacity to teach and to learn from teaching.

The roots of intersubjectivity are evident early in infancy. By age 2 to 3 months, infants show greater animation and interest when their mothers respond to their actions than when their mothers behave in ways that are independent of those actions (Murray & Trevarthen, 1985). By age 6 months, infants can learn novel behaviors by observing other people's behavior (Collie & Hayne, 1999).

These developments set the stage for the emergence of a process that is at the heart of intersubjectivity—**joint attention.** In this process, infants and their social partners intentionally focus on a common referent in the external environment. The emergence of joint attention is evident in numerous ways. Between the ages of 9 and 15 months, infants increasingly look toward the objects that their social partners are looking at, adjust where they are looking if the partner looks at a new object, and actively direct a partner's attention toward objects that interest them (Adamson, Bakeman, & Deckner, 2004; Akhtar & Gernsbacher, 2008; Moore, 2008).

Joint attention greatly increases children's ability to learn from other people. One important example involves language learning. When an adult tells a toddler the name of an object, the adult usually looks or points directly at it; children who are looking at the same object are in a better position to learn what the word means than ones who are not (Baldwin, 1991). Indeed, the degree of success infants have in following other people's gaze predicts their later vocabulary development (Brooks & Meltzoff, 2008). The effectiveness of such joint attention is also reflected in the fact that the younger the age at which infants begin to show joint attention, the faster their subsequent language acquisition (Carpenter, Nagell, & Tomasello, 1998).

Intersubjectivity continues to develop well beyond infancy, as children become increasingly able to take the perspectives of other people. For example, 4-year-olds are more likely than 3-year-olds to reach agreement with peers on the rules of games they are about to play and the roles that each child will assume (Goncu, 1993). The continuing development of such perspective-taking abilities also leads to school-age children's increasing ability to teach and learn from each other (Gauvain, 2001).

Social Scaffolding

When putting up tall buildings, construction workers use metal frameworks called scaffolds, which allow them to work high above the ground. Once a building's main structure is in place, it can support further work on its own, thus allowing the scaffolding to be removed. In an analogous fashion, children's learning is aided by **social scaffolding,** in which more competent people provide a temporary framework that supports children's thinking at a higher level than children could manage on their own (Wood, Bruner, & Ross, 1976). Ideally, this framework includes explaining the goal of the task, demonstrating how the task should be done, and helping the child execute the most difficult parts. This, in fact, is the way parents tend to teach their children (Pratt, Kerig, Cowan, & Cowan, 1988; Saxe, Guberman, & Gearhart, 1987; Wood, 1986). Through the process of social scaffolding, children become capable of working at a higher level than if they had not received such help. At first, this higher-level functioning requires extensive support; then it requires less and less and eventually it becomes possible without any support. The higher the quality of the scaffolding—that is, the more that instructional

joint attention a process in which social partners intentionally focus on a common referent in the external environment

social scaffolding a process in which more competent people provide a temporary framework that supports children's thinking at a higher level than children could manage on their own efforts are directed at the upper end of the child's capabilities—the greater the learning (Conner, Knight, & Cross, 1997; Gauvain, 2001). The goal of social scaffolding—to allow children to learn by doing—is the same as that of guided participation, but scaffolding tends to involve more explicit instruction and explanation, whereas guided participation tends to involve adults' organizing tasks so that children can take increasingly active and responsible roles in them.

The quality of scaffolding tends to increase with increases in the age and experience of those providing it. Adults' scaffolding tends to be of higher quality than children's, and older children's, of higher quality than younger ones'. In part, this is because adults usually encourage learners to participate actively in the task and help them learn strategies for proceeding independently in the future (Gauvain, 2001). Children, in contrast—even ones who are as knowledgeable about a task as adults are—often just tell less knowledgeable peers what to do or do the task themselves. Not surprisingly, 5- to 9-year-olds who have previously solved problems with their parents do better on similar new problems than peers who have previously solved the same kinds of problems with other children (Radziszewska & Rogoff, 1988).

By providing their children with social scaffolding, parents enable them to play with toys and other objects in more advanced ways than would otherwise be possible, which helps the children learn.

One particularly important way in which parents use scaffolding is in helping children form **autobiographical memories,** explicit memories of events that took place at specific times and places in the individual's past (Nelson & Fivush, 2004). Autobiographical memories include information about one's goals, intentions, emotions, and reactions relative to these events. Over time, these memories become strung together into a more or less coherent narrative about one's life.

When discussing past experiences with their young children, some mothers encourage them to provide many details about past events and often expand on the children's statements. Such a mother might reply to her toddler's statement "Bird fly away" by saying, "Yes, the bird flew away because you got very close to it and it was scared of you." Such statements help children remember their experiences by improving their encoding of key information (distance from the bird) and their appreciation of the causal relations among events (Boland, Haden, & Ornstein, 2003; McGuigan & Salmon, 2004). Other mothers ask fewer questions and rarely elaborate on what their children say. Children whose mothers use the more elaborative style remember more about the events than do children whose mothers rarely elaborate (Haden, Hayne, & Fivush, 1997; Harley & Reese, 1999; Leichtman et al., 2000). (As discussed in Box 4.4, concepts from sociocultural theories have also proved useful for improving education in classrooms.)

The importance of the sociocultural persective in understanding cognitive development will be especially clear in the upcoming chapters on language development, conceptual development, and intelligence.

applications 4.4

Educational Applications of Sociocultural Theories

For some time, the educational system of the United States has been criticized for promoting rote memorization of facts rather than deep understanding; for promoting competition rather than cooperation among students; and for generally failing to create enthusiasm for learning (Bruner, 1996; National Research Council, 2001). The emphasis of sociocultural theories on the role of culture in learning implies that one way to improve schooling is to change the culture of schools. The culture should be one in which instruction is aimed at deep understanding, in which learning is a cooperative activity, and in which learning a little makes children want to learn more.

One impressive attempt to meet these goals is Ann Brown's (1997) *community-of-learners* program. Its efforts to build communities of learners have focused on 6- to 12-year-olds, most of them African-American children attending inner-city schools in Boston, Massachusetts, and Oakland, California. The main curriculum consists of projects that require research on some large topic, such as interdependence between animals and their habitats. The class divides into small groups, each of which focuses on a particular aspect of the topic. With the topic of the interdependence between animals and habitats, for example, one group might study predator–prey relations; another, reproductive strategies; another, protection from the elements; and so on.

At the end of roughly 10 weeks, new groups are formed, each including one child from every original group. Children in the new groups are asked to solve a problem that encompasses all the aspects studied by the previous groups, such as designing an "animal of the future" that would be particularly well adapted to its habitat. Because each child's participation in the previous group has resulted in the child's gaining expertise on the aspect of the problem studied by that group, and because no other child in the new group has that expertise, all of the children's contributions are essential for the new group to succeed. This has been labeled the *jigsaw approach,* because, as in a jigsaw puzzle, each piece is necessary for the solution.

A variety of people help foster such communities of learners. Classroom teachers introduce the big ideas of the unit, encourage the class to pool its knowledge to achieve deeper understanding, push children to provide evidence for their opinions, and ask them to summarize what they know and to identify new learning goals. Outside experts are brought to classrooms to lecture and answer questions about the topic. Children and teachers exchange e-mails with groups at other schools who are working on the same problem to see how they are approaching issues that arise.

Communities of learners provide both cognitive and motivational benefits for children. Participation in such groups helps children to become increasingly adept at constructing high-quality solutions to the problems they try to solve. It also helps them learn such general skills as identifying key questions and comparing alternative solutions to a problem. Finally, because the children all depend on each other's contributions, the community-of-learners approach encourages mutual respect and individual responsibility for the success of the entire group. In short, the approach creates a culture of learning.

review:

Sociocultural approaches view children as social beings, shaped by, and shaping, their cultural contexts. These approaches emphasize that children develop in a cultural context of other people and human inventions, such as symbol systems, artifacts, skills, and values. Through guided participation, more knowledgeable people help children gain skills in using these cultural tools; using the tools, in turn, further transforms children's thinking. Culture is made possible by the human propensity to think and learn and by our ability to establish intersubjectivity with other people. Through processes such as social scaffolding and the creation of communities of learners, older and more skilled individuals help children acquire the skills, knowledge, and values of their culture.

Dynamic-Systems Theories

Like all biological processes, thinking serves an adaptive purpose: it enables people and other animals to devise plans for attaining goals. However, attaining goals also requires the ability to take action; without this ability, thinking would be pointless. What purpose would it serve for an infant to figure out that she needed to remove an obstacle to obtain a toy if she were incapable of moving the obstacle and accurately reaching for and grasping the toy? As this analysis implies, any variable that influenced the infant's ability to execute the plan—for example, her ability to accurately perceive the toy's position and to maintain a stable posture while reaching—would influence her likelihood of achieving the goal. However, despite this inherent connection between thinking and acting, most theories of cognitive development have focused exclusively on thinking and ignored the development of the actions that allow children to realize the fruits of their mental labor.

dynamic-systems theories a class of theories that focus on how change occurs over time in complex systems

One increasingly influential exception to this generalization is **dynamic-systems theories,** which are a class of theories that focus on how change occurs over time in complex systems. Research that reflects this perspective indicates that detailed analyses of the development of even basic actions, such as crawling, walking, reaching, and grasping, yield surprising and impressive insights into how development occurs. For example, dynamic-systems research has shown that improved reaching influences the development of infants' free (i.e., spontaneous) play with objects. In particular, it allows infants to play with objects in more advanced ways, such as organizing them into categories or interesting configurations (Spencer et al., 2006; Thelen & Corbetta, 1994). Dynamic-systems research also has shown that the onset of crawling changes infants' relationships with family members, who may be thrilled to see their baby attain an important motor milestone but also may find themselves having to be much more watchful and controlling as the child tries to explore anything he or she can get to (Campos, Kermoian, & Zumbahlen, 1992).

Another contribution of dynamic-systems research has been to demonstrate that the development of seemingly simple actions is far more complex and interesting than previously realized. For example, such research has overturned the traditional belief that physical maturation leads infants to attain motor milestones in stages, at roughly the same age, in the same way, and in a steady progression. It has shown instead that individual children acquire skills at different ages and in different ways, and that their development entails regressions as well as progress. One example of this type of research is a longitudinal study of the development of infants' reaching conducted by Esther Thelen, who, along with her colleague Linda Smith, was the cofounder of the dynamic-systems approach to cognitive development. In this particular study, Thelen and colleagues (1993) repeatedly observed the reaching efforts of four infants during their first year. Using high-speed motion-capture systems and computer analysis of the infants' muscle movements, they found that due to individual differences in such factors as the infants' physiology, activity level, arousal, motivation, and experience, each child faced different challenges in his or her attempts to master reaching. The following observations illustrate some of the complexities these researchers discovered, including fluctuations in infants' developmental progress, variability in the ages at which they reach developmental milestones, and the differing challenges they must overcome:

> Infants differed dramatically in the ages of the transition (from no reaching to reaching). Whereas Nathan reached first at 12 weeks, Hannah and Justin did not attain this milestone until 20 weeks of age. [In addition,] the infants showed periods of rapid change, plateaus, and even regressions in performance . . . three of the four infants showed an epoch where straightness and smoothness appeared to get worse after some improvement . . . Finally, there was in Nathan, Justin, and Hannah a rather discontinuous shift to better, less variable performance . . . Gabriel's transition to stability was more gradual.
>
> (Thelen & Smith, 1998, pp. 605, 607)

The electrodes attached to the arms of this baby in Esther Thelen's lab are connected to a computer, so the infant's reaching movements can be analyzed in great detail.

> Infants must individually discover the appropriate speeds from the background of their characteristic styles. Gabriel, for example, had to damp down his very vigorous movements in order to successfully reach, and he did. In contrast, Hannah, who moved slowly and spent considerable time with her hands flexed near her face, had to activate her arms more to extend them out in front of her. . . . Reaching is thus sculpted from ongoing movements of the arms, through a process of modulating what is in place . . . As infants become older, their attention becomes more focused, and their perceptual discrimination improves, and their memories get better, and their movements become more skilled. A rich, complex, and realistic account of change must include this dynamic interplay.
>
> (Thelen, 2001, pp. 172, 182)

These quotations help to convey what is meant by the label "dynamic systems." As suggested by the term *dynamic*, these theories depict development as a process in which change is the only constant. Whereas most approaches to cognitive development hypothesize that development entails long periods of relatively stable stages, rules, or core theories separated by relatively brief transition periods, dynamic-systems theories propose that at all points in development, thought and action change from moment to moment in response to the current situation, the child's immediate past history, and the child's longer-term history of actions in related situations. Thus, Thelen and Smith (1998) noted that the development of reaching included regressions as well as improvements, and Thelen (2001) described how differences in Hannah's and Gabriel's early reaches influenced their later path to skilled reaching.

As suggested by the second term in the label, this theory depicts each child as a well-integrated system, in which many subsystems—perception, action, attention, memory, language, social interaction, and so on—work together to determine behavior. For instance, dynamic-systems analyses have revealed that performance on tests of object permanence, Piaget's classic measure of infants' cognitive development, is affected not only by conceptual understanding but also by a host of other factors, including changes in attention, perception, memory, and motor skills (see discussion of the A-not-B error on pages 168–169.) The assumptions that development is dynamic and that it functions as an organized system are central to the theory's perspective on children's nature.

View of Children's Nature

Dynamic-systems theories are the newest of the five types of theories discussed in this chapter, and their view of children's nature incorporates influences from each of the others. Like Piaget's theory, dynamic-systems theories emphasize children's innate motivation to explore the environment; like information-processing theories, they emphasize precise analyses of problem-solving activity; like core-knowledge theories, they emphasize early emerging competencies; and like sociocultural theories, they emphasize the formative influence of other people. These similarities to other theories, as well as differences from them, are evident in dynamic-systems theories' emphasis on motivation and the role of action.

Motivators of Development

To a greater extent than any of the other theories except Piaget's, dynamic-systems theories emphasize that from infancy onward, children are strongly motivated to learn about the world around them and to explore and expand their own capabilities (von Hofsten, 2007). This motivation to explore and learn is clearly apparent in the fact that children persist in practicing new skills even when they possess well-practiced skills that are more efficient. Thus, toddlers persist in their first unsteady efforts to walk, despite the fact that crawling would get them where they want to go more quickly and without the risk of falling (Gibson & Pick, 2000).

Unlike Piaget's theory, but like sociocultural and some core-knowledge theories, dynamic-systems theories also emphasize infants' interest in the social world as a crucial motivator of development. As noted in our discussion of the *active child* in Chapter 1, even newborns prefer attending to the sounds, movements, and features of the human face over almost any alternative stimuli. By 10 to 12 months of age, infants' interest in the social world is readily apparent in the emergence of intersubjectivity (page 161), as infants quite consistently look where the people interacting with them are looking and direct the attention of others to things they themselves find interesting (Deák, Flom, & Pick, 2000; von Hofsten, Dahlström, & Fredricksson, 2005). Dynamic-systems theorists have emphasized that observing other people, imitating their actions, and attracting their attention are all potent motivators of development (Fischer & Biddle, 2006; von Hofsten, 2007).

The Centrality of Action

Dynamic-systems theories are unique in their pervasive emphasis on how children's specific actions shape their development. Piaget's theory asserts the role of actions during the sensorimotor stage, but dynamic-systems theories place greater emphasis than any other theory on how actions contribute to development throughout life. This focus on the developmental role of action has led to a number of interesting discoveries. For example, reaching for objects helps infants infer the goals of other people's reaches (von Hofsten, 2007). These inferences appear to reflect the operation of *mirror neurons*, neurons that are activated when one observes another person perform a given goal-directed action, in effect, neurally "mirroring" the observed behavior as though one were performing it oneself (Umiltá et al., 2001). Such neurons are thought to enable infants to understand other people's reaches by mapping the sight of them onto the infants' motor and goal representations of their own reaches. Another example of infants' learning from actions comes from research in which infants were outfitted with Velcro mittens that enabled them to "grab" and explore Velcro-covered objects that they otherwise could not have picked up. After two weeks of experience grabbing the Velcro-covered objects with the Velcro-covered mittens, infants showed greater ability to grab and explore ordinary objects without gloves than did other infants of the same ages (Needham, Barrett, & Peterman, 2002).

The ways in which children's actions shape their development extend well beyond reaching and grasping in infancy. Actions influence categorization: in one study, encouraging children to move an object up and down led to their categorizing it as one of a group of objects that were easiest to move in that way, whereas encouraging children to move the same object side to side led them to categorize it as one of a group of objects that were easiest to move in that way (Smith, 2005). Actions also affect vocabulary acquisition and generalization (Gershkoff-Stowe, Connell, & Smith, 2006; Samuelson & Horst, 2008): for example, experimental manipulations that lead children to state an incorrect name for an object impair the child's future attempts to learn the object's correct name. In addition, actions shape memory, as demonstrated by research in which children's past attempts to locate and dig up objects they had earlier seen being hidden in a sandbox alter their recall of where they saw the objects being subsequently rehidden. That is, their new searches are in-between the past and present locations, as if they were a compromise between their memory of the new hiding place and of the location where they had originally looked (Schutte, Spencer, & Schöner, 2003; Zelazo, Reznick, & Spinazzola, 1998). Even in adulthood, categorization, vocabulary acquisition, conceptual understanding, and memory are influenced by actions (Barsalou, 2005). Thus, just as thinking shapes actions, actions shape thinking.

Central Development Issues

Two developmental issues that are especially prominent in dynamic-systems theories are how the cognitive system organizes itself and how it changes.

Self-Organization

Dynamic-systems theories view development as a process of self-organization in which "pattern and order emerge from interactions of the components of a complex system without explicit instruction either in the organism itself or from the environment" (Thelen & Smith, 1998, p. 564). In other words, development is neither innately specified in the genome nor wholly dependent upon instruction from other people. Instead, the child's interactions with the physical and social environments produce an organized, flexible, and adaptive behavioral system. Although these ideas regarding self-organization resemble Piaget's concepts of assimilation, accommodation, and equilibration, as well as core-knowledge concepts regarding children's theories, dynamic-systems research has demonstrated more precisely how the organizational process operates.

Self-organization involves bringing together and integrating components as needed to adapt to a continuously changing environment (Spencer et al., 2006). The organizational process is sometimes called *soft assembly*, because the components and their organization change from moment to moment and situation to situation, rather than being governed by rigid rules that are consistently applied across time and situations. The types of research to which this perspective leads are illustrated particularly well by certain studies of the A-not-B error that 8- to 12-month-olds typically make in Piaget's classic object-permanence task. As noted earlier, this error involves infants' searching for a toy where they had previously found it (location A), rather than where they last saw it being hidden (location B). Piaget (1954) explained the A-not-B error by hypothesizing that before their 1st birthday, infants lack a clear concept of the permanent existence of objects.

In contrast, viewing the A-not-B error from a dynamic-systems perspective suggested that many factors other than conceptual understanding influence performance on the object permanence task. In particular, Smith, Thelen, Titzer, and McLin (1999) argued that babies' previous reaching toward location A produces a habit of reaching there, which influences their behavior when the object is subsequently hidden at location B. On the basis of this premise, the researchers made several predictions that were later borne out. One was that the more often babies had found an object by reaching to one location, the more likely they would be to reach there again when the object was hidden at a different location. Also supported was the prediction that increasing the memory demands of the task by not allowing infants to search for the object for 3 seconds after it was hidden at the B location would increase the likelihood of infants' reaching to location A (Clearfield et al., 2009). The reasoning here was that the strength of the new memory would fade rapidly relative to the fading of the habit of reaching to the A location. Dynamic-systems theory also suggested that infants' attention would influence their object-permanence performance. Consistent with this view, manipulating infants' attention by tapping one of the locations just as the infants were about to reach usually resulted in their reaching to the tapped location, regardless of where the object was hidden.

In perhaps the most striking test of such predictions, researchers demonstrated that putting small weights on infants' wrists after the infants had reached to location A but before the object was hidden at location B improved object-permanence performance (Diedrich, Thelen, Smith, & Corbetta, 2000). The researchers had predicted this effect by reasoning that the addition of the wrist weights would require the use of different muscle tensions and forces to reach for the object and consequently would disrupt the infants' habit of reaching to the A location. Thus, rather than providing a pure measure of conceptual understanding, performance on the object-permanence task appears to also reflect the combined influence of the strength of the habit of reaching to location A, the memory demands of the current task, the infants' current focus of attention, and the match between the muscular forces required to reach in the old and new situations.

How Change Occurs

Dynamic-systems theories posit that changes occur through mechanisms of variation and selection that are analogous to those that produce biological evolution (Fischer & Biddell, 2006; Steenbeck & Van Geert, 2008). In this context, *variation* refers to different behaviors being generated to pursue the same goal. As noted in Chapter 1, for example, to add two small numbers, a 1st grader might sometimes count from 1, other times count from the larger number, and yet other times retrieve the answer from memory. *Selection* involves an increasing choice of behaviors that are effective in meeting goals and a decreasing choice of less effective behaviors. For example, over the course of 1st grade, children increasingly retrieve answers to the simpler problems (e.g., 3 + 3), increasingly count from the larger addend when that is easy to do (e.g., 3 + 9), and decreasingly count from 1 on both types of problems (Geary, 2006).

The variability of behavior often waxes and wanes in a cyclical fashion over the course of learning (Siegler, 2006). On number-conservation problems, for example, children first use a variety of incorrect approaches, then converge on a single incorrect approach (the longer row has more objects), then oscillate between that approach and the correct approach of considering on whether any objects were added or subtracted, and finally consistently use the correct approach (Siegler, 1981; 1995).

Such variation is important, because children whose initial goal-directed behavior varies to a greater extent tend to learn more from relevant experience. For example, children who initially use a greater number of strategies to solve number-conservation problems learn more from feedback on the correctness of their answers (Church & Goldin-Meadow, 1986; Siegler, 1995). This positive relation between variability and learning has emerged in numerous contexts, including mathematical reasoning (Alibali & Goldin-Meadow, 1993), scientific reasoning (Perry & Lewis, 1999; Schauble, 1996), and logical deduction (van der Maas & Molenaar, 1992). A possible explanation for the positive relation between variability and learning may be that using multiple approaches to achieving a goal may indicate openness to new experiences and approaches (Goldin-Meadow, 2001).

Children's selection among alternative approaches reflects several influences (Siegler, 2006). Most important is the *relative success* of each approach in meeting a particular goal: as children gain experience, they increasingly rely on approaches that produce desired outcomes. Another important consideration is *efficiency*: children increasingly choose approaches that meet goals more quickly or with less effort than do other approaches. A third consideration is *novelty*, the lure and challenge of trying something new. Children sometimes choose new approaches that are no more efficient, or even less efficient, than an established alternative but that have the potential to become more efficient. They may try to walk down steep ramps when it would be quicker and less dangerous to slide down them (Adolph, 1997), and they use newly generated memory and arithmetic strategies when older approaches temporarily would be equally or more effective (Miller & Seier, 1994; Siegler & Jenkins, 1989). Such a novelty preference tends to be adaptive, because with practice, a strategy that is initially less efficient than existing approaches often becomes more efficient (Wittman, Daw, Seymour, & Dolan, 2008). As discussed in Box 4.5, the insights that dynamic-systems theories have brought to the question of how change occurs has led to useful applications as well as theoretical progress.

applications 4.5

Educational Applications of Dynamic-Systems Theories

As noted in Chapter 2 (page 76), children born prematurely with low birth weight are more likely than other children to encounter developmental difficulties; one of these is the slower emergence and refinement of reaching (Fallang, Saugstad, Grogaard, et al., 2003). These delays in reaching slow the development of brain areas involved in reaching (Martin, Choy, Pullman, & Meng, 2004) and limit infants' ability to explore and learn about objects (Lobo, Galloway, & Savelsbergh, 2004). A variety of seemingly reasonable efforts to improve preterm infants' reaching, such as guiding their arms through reaching movements, have yielded discouraging results (Blauw-Hospers & Hadders-Algra, 2005).

In contrast, a recent intervention based on dynamic-systems research was quite successful (Heathcock, Lobo, & Galloway, 2008). This intervention was inspired by Thelen and colleagues' (1993) finding that a slowness to self-initiate arm activity impedes the development of reaching and by Needham and colleagues' (2002) finding that providing young infants with experience in reaching for and grabbing Velcro-patched objects while wearing Velcro-covered mittens improves the infants' later ability to reach for and grab ordinary objects barehanded.

The researchers began their intervention by requesting that caregivers of preterm infants in an experimental group provide the infants with special movement experiences. Specifically, the caregivers were asked to encourage infants' arm movements by (1) tying a bell to the infants' wrists so that arm movements would make it ring, presumably motivating further movements, and (2) placing Velcro mittens on the infants' hands to allow them to reach for and grab Velcro-patched toys held in front of them. The caregivers were asked to do this at home five times per week for eight weeks.

Caregivers of preterm infants in a control group were asked to provide their infants with special social experiences that included singing to and talking with the infants on the same intervention schedule as the experimental group's. Periodically, the infants in both groups were brought to the lab to allow project personnel to observe their reaching and exploration under controlled circumstances and during free play.

As might be expected, the reaching of preterm infants in both groups improved over the eight weeks of the study. However, the infants in the experimental group improved to a greater degree. They more often touched toys that were held in front of them, and more often did so with the inside rather than the outside part of their hand, as is needed for grasping objects. The difference between infants in the experimental and control groups grew steadily over the course of the laboratory observations. Especially impressive, infants who were given the movement experience actually reached more often at the end of the experiment than did full-term same-age peers who were not given the movement experience. Such experiences may also help preterm infants avoid other types of cognitive and motor impairments that are partially caused by delayed development of reaching.

review:

Dynamic-systems theories view children as ever-changing, well-integrated organisms that combine perception, action, attention, memory, language, and social influences to produce actions that satisfy goals. From this perspective, children's actions are shaped by both their remote and recent past history, their current physical capabilities, and their immediate physical and social environment. The actions, in turn, are viewed as shaping the development of categorization, conceptual understanding, memory, language, and other capabilities. Dynamic-systems theories are unique in their emphasis on how children's actions shape their development and in the range of developmental influences they consider with regard to particular capabilities.

Chapter Summary

Theories of development are important because they provide a framework for understanding important phenomena, raise major issues regarding human nature, and motivate new research. Five major theories of cognitive development are Piagetian, information-processing, core-knowledge, sociocultural, and dynamic-systems.

Piaget's Theory

- Among the reasons for the longevity of Piaget's theory are that it vividly conveys the flavor of children's thinking at different ages, extends across a broad range of ages and content areas, and provides many fascinating and surprising observations of children's thinking.
- Piaget's theory is often labeled "constructivist," because it depicts children as actively constructing knowledge for themselves in response to their experience. The theory posits that children learn through two processes that are present from birth—assimilation and accommodation—and that they balance their contributions through a third process, equilibration. These processes produce continuities across development.
- Piaget's theory divides cognitive development into four broad stages: the sensorimotor stage (birth to age 2), the preoperational stage (ages 2 to 7), the concrete operations stage (ages 7 to 12), and the formal operations stage (age 12 and beyond). These stages reflect discontinuities in development.
- In the sensorimotor stage, infants' intelligence is expressed primarily through motor interactions with the environment. Infants gain understanding of concepts such as object permanence and become capable of deferred imitation during this period.
- In the preoperational stage, children become able to represent their experiences in language, mental imagery, and thought, but because of cognitive limitations such as egocentrism and centration, they have difficulty solving many problems, including Piaget's various tests of conservation and tasks related to taking the perspective of others.
- In the concrete operations stage, children become able to reason logically about concrete objects and events but have difficulty reasoning in purely abstract terms and in succeeding on tasks requiring hypothetical thinking, such as the pendulum problem.
- In the formal operations stage, children gain the cognitive capabilities of hypothetical thinking.
- The primary weaknesses of Piaget's theory are that it depicts children's thinking as being more consistent than it is, underestimates infants' and young children's cognitive competence, understates the contribution of the social world to cognitive development, and only vaguely describes the mechanisms that give rise to thinking and cognitive growth.

Information-Processing Theories

- Information-processing theories focus on the specific mental processes that underlie children's thinking. Even in infancy, children are seen as actively pursuing goals, encountering processing limits, and devising strategies that allow them to surmount the processing limits and attain the goals.
- The development of memory and learning in large part reflects improvements in basic processes, strategies, and content knowledge.
- Basic cognitive processes allow infants to learn and remember from birth onward. Among the most important basic processes are association, recognition, generalization, and encoding.
- The use of strategies enhances learning and memory beyond the level that basic processes alone could provide. Rehearsal and selective attention are two important strategies.
- Increasing content knowledge enhances memory and learning of all types of information.
- Among the leading contributors to the growth of problem solving are the development of planning and analogical reasoning.

Core-Knowledge Theories

- Core-knowledge theories are based on the view that children begin life with a wide range of specific cognitive competencies.
- Core-knowledge approaches also hypothesize that children are especially adept at acquiring evolutionarily important information, such as language, spatial layouts, and face recognition.
- These approaches also posit that, from early ages, children organize information about the most important domains into informal theories, such as theories of physics, biology, and psychology.

Sociocultural Theories

- Starting with Vygotsky's theory, sociocultural theories have focused on the way that the social world molds development. These theories emphasize that development is shaped not only by interactions with other people and the skills learned from them but also by the artifacts with which children interact and the values and traditions of the larger society.
- Sociocultural theories view humans as differing from other animals in their propensity to teach and their ability to learn from teaching.
- Establishing intersubjectivity between people through joint attention is essential to learning.
- Sociocultural theories describe people as learning through guided participation and social scaffolding, in which others who are more knowledgeable support the learner's efforts.

Dynamic-Systems Theories

- Dynamic-systems theories view change as the one constant in development. Rather than depicting development as being organized into long periods of stability and brief periods of dramatic change, these theories propose that there is no period in which substantial change is not occurring.
- These theories also view each person as a unified system that, in order to meet goals, integrates perception, action, categorization, motivation, memory, language, conceptual understanding, and knowledge of the physical and social worlds.
- Dynamic-systems theories view development as a self-organizing process that brings together components as needed to adapt to a continuously changing environment.
- Attaining goals requires action as well as thought. Thought shapes action, but it also is shaped by action.
- Just as variation and selection produce biological evolution, they also produce cognitive development.

Critical Thinking Questions

1. Piaget's theory has been prominent for more than 80 years. Do you think it will continue to be prominent for the next 20 years as well? Why or why not?
2. Do you think that the term *egocentric* is a good description of preschoolers' overall way of seeing the world? On the basis of what you learned in this chapter and your own experience, explain your answer and indicate in what ways preschoolers are egocentric and in what ways they are not.
3. Information-processing analyses tend to be more specific about cognitive processes than do analyses generated by other theories. Do you see this specificity as an advantage or a disadvantage? Why?
4. Does the evolutionary perspective of core-knowledge theories seem sound to you? Explain and give examples of how learning in core-knowledge domains may or may not have contributed to human evolution.
5. Imagine that you are trying to help a 6-year-old learn a skill that you possess. Using the ideas of guided participation and social scaffolding, describe how you might go about this task.
6. Dynamic-systems theories reflect influences of each of the other theories reviewed in this chapter. Which theoretical influence do you think is strongest: Piagetian, information-processing, core-knowledge, or sociocultural? Explain your reasoning.

Key Terms

adaptation, p. 131
organization, p. 131
assimilation, p. 131
accommodation, p. 131
equilibration, p. 131
sensorimotor stage, p. 133
preoperational stage, p. 133
concrete operational stage, p. 133
formal operational stage, p. 133
object permanence, p. 134
A-not-B error, p. 134
deferred imitation, p. 135
symbolic representation, p. 136
egocentrism, p. 136
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conservation concept, p. 137
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sensory memory, p. 146
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domain specific, p. 156
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autobiographical memory, p. 163
dynamic-systems theories, p. 165