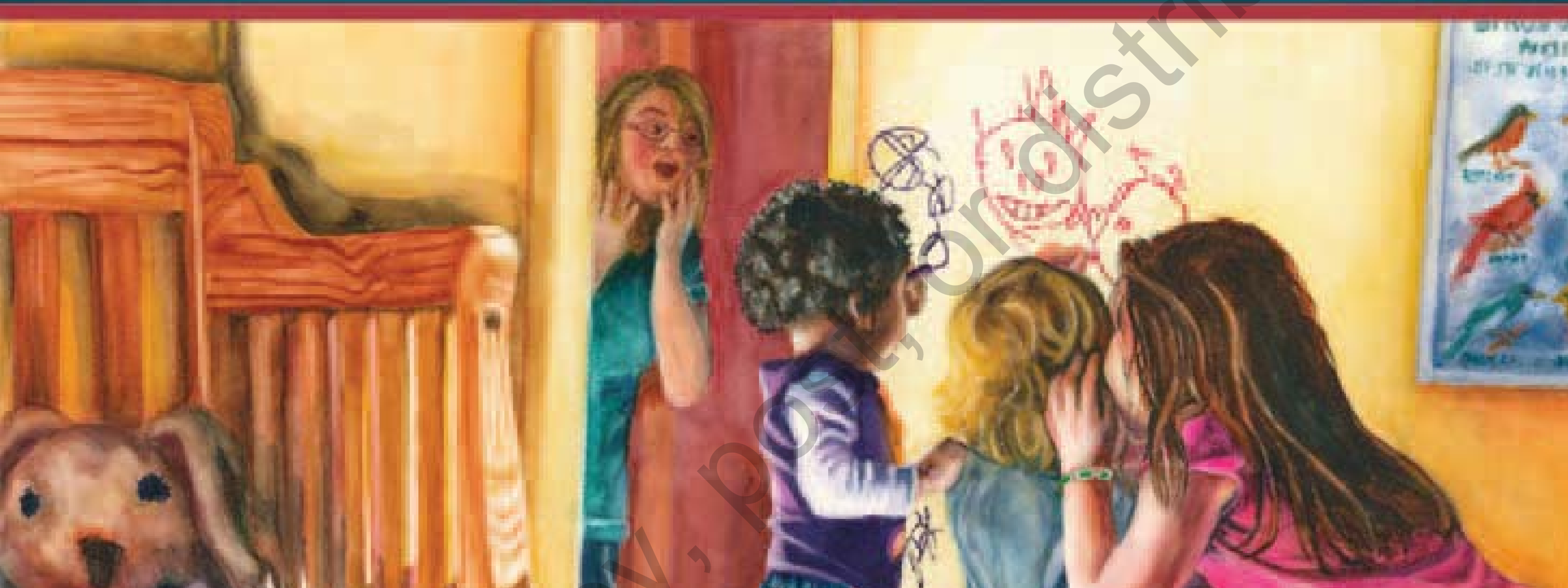
SECOND EDITION

Cognitive Development

Infancy Through Adolescence



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CHAPTER 10

REPRESENTATION AND COMPLEX COGNITIVE SKILLS IN MIDDLE CHILDHOOD

We've now caught up on developments in "basic" cognitive processes—such things as perception, attention, and memory. Cognitive psychologists often contrast these processes with "higher-order" cognitive processes, which are said to be ones that make use of the outputs from basic cognitive processes. Included in higher-order cognitive processes are thinking, reasoning, decision making, problem solving, and other related complex processes. The topic of how information is organized into a knowledge base—how instances are classified and mentally represented—is one that comes between basic and higher-order cognition, and it will be the topic we begin with in this chapter.

We will take up the topic of cross-cultural differences in cognitive development here. Specifically, we'll begin by looking at non-Western cultures in which schooling is not the major occupation of children in middle childhood. Instead, these children are typically apprenticing to their parents or other elders, learning a trade or vocation under the tutelage of an expert. We will contrast that kind of cognitive development with the kind experienced by children in Western cultures, focusing on the development of academic skills.

DEVELOPING A WIDER AND DEEPER KNOWLEDGE BASE

As you may recall, semantic memory holds information in our knowledge base. Like episodic memory, semantic memory holds information that was previously learned. For example, your knowledge that a dollar is worth the same as 10 dimes or 20 nickels or 100 pennies is not innate—probably somewhere about the time when you were 5 or 6 years old you started to learn these facts. Unlike episodic memories, semantic memories don't seem to hold "time tags" or information about your personal circumstances of when you first learned the information. Thus, while you very likely could provide me with a narrative about where you were when you first heard about, say, the Boston Marathon bombing, you are very *unlikely* to provide such a narrative about where you were when you learned that a dime was worth two nickels.

One of the more noticeable aspects of cognitive development in middle childhood is the growth of the knowledge base. School-aged children in the United States learn an incredible amount of what adults would consider "basic" information—letters of the alphabet; how to read; addition, subtraction, multiplication, and division facts; historical and geographical facts; information about certain authors; and information about animals, planets, and machines, to take just a few examples from my children's elementary school's curriculum. Add to that knowledge of domains that aren't formally taught in schools (at least not when my children were small)—Pokémon characters, Webkinz website rules of operation, or characters from the *Captain Underpants* or *Harry Potter* book series or the *Spy Ops* television shows are examples that come immediately to my mind, courtesy of my children's childhoods.

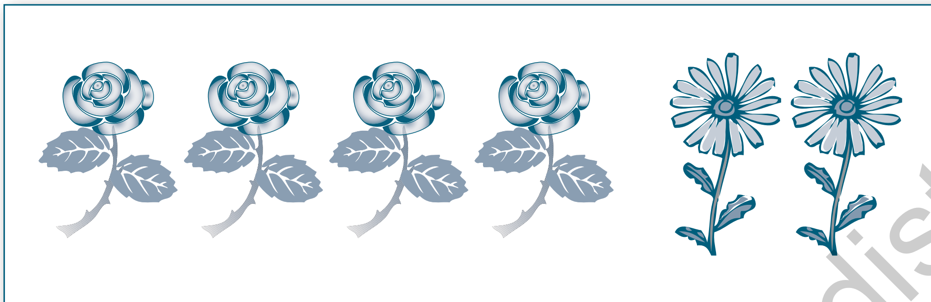
When that much information is entering storage, issues immediately arise as to how it all gets organized. To understand this idea, consider the files on your personal computer. My bet is that when you first started storing files on a computer you may have created a folder called "My Folder" on the hard drive and simply stuck all your files within it. When you have a reasonable number of individual files, such a system works just fine. But over time as you created more and more files, you probably had to develop a more complex system of filing, including the creation of different folders. Maybe you had one folder for all your school-related files, another one for all your photos, another one for all the letters you wrote, and so forth. But over time, you likely found that an increasingly differentiated system was required. Finding a file called "Letter to Aunt Sarah" only works if you've written just one letter to her, ever. If you start a long correspondence with her, however, you'll need to differentiate file names and probably file all your letters to her in the same place for easy access.

Analogously, children need to find efficient ways of storing and representing all of the knowledge they acquire. How they do that is certainly a matter of active debate and discussion in the field (see S. Gelman & Kalish, 2006, for an overview). Here, we will focus on the development of concepts in middle childhood. As before, we will be continuing a discussion begun in Chapter 8 about conceptual development in the preschool years. There, we saw that children revise information about their concepts as they acquire more information, experience, and expertise in a domain. Young children sometimes group things together based on their perceptions (so a toddler might call a lion a "kitty" or a "doggie"), but when children have skeletal principles in a domain, they use those to reason about new instances they encounter in trying to figure out what the new instance is an instance of.

Understanding Class Inclusion

We've previously reviewed the Piagetian theory of concrete operations and looked in depth at children's performance on such "hallmark" tasks as the conservation task. Another famous Piagetian task thought to indicate the presence of concrete operations is the **class-inclusion task** (Inhelder & Piaget, 1964). This task is depicted in Figure 10.1, which shows a line drawing of four roses and two daisies.

Figure 10.1 Depiction of stimuli for a Piagetian class-inclusion task; children are asked the question, "Who would have more, the person who had the flowers or the person who had the roses?"



In a typical Piagetian scenario, the child is asked to point first to all the roses, then to all the daisies, and then to all the flowers. Correct responses ensure that the child understands all the terms that will be used in the critical question and, further, understands the hierarchical nature of the concepts *rose, daisy,* and *flower.* That is, the child understands that the term *flower* encompasses other terms that name specific kinds of flowers.

Now the child is asked, "Who would have more, the person who had the flowers or the person who had the roses?" Typically, up until about the age of 8, the child will claim that there are more roses than flowers (McCabe, Siegel, Spence, & Wilkinson, 1982). This is so, even though he previously agreed that roses are flowers! According to Piagetian theory, the child has trouble (until concrete operations are firmly established) keeping both the part (roses) and whole (flowers) classes in mind simultaneously. Although asked to compare two different levels of the hierarchy to each other, the child instead compares only entities at the same level of the hierarchy and compares the roses to the less numerous daisies.

It would appear from these findings that younger children lack an important ability that older children readily display. But once again, Piaget's interpretation of children's performance on his original task was challenged by subsequent researchers. In particular, Ellen Markman (Markman, Horton, & McLanahan, 1980; Markman & Siebert, 1976) argued that younger children are more likely to understand **collections** and mentally impose this structure on class-inclusion task stimuli.

What is a collection? According to Markman and Siebert (1976), a collection is a term such as *family* or *forest* or *pile* that describes not only a group of individuals (e.g., *people* or *trees* or *blocks*), but individuals who also have a specific organization in relation to each other. For example, one can presumably tell if something is a tree or not independently of its spatial relationship to other trees. However, one cannot tell if a tree is in a forest without knowing about these spatial relationships.

Markman et al. (1980) argued that collections are a psychologically more coherent principle of hierarchical organization than are classes and that children naturally impose a collection structure on class-inclusion questions. And, indeed, kindergarteners and first graders tested by Markman and Siebert (1976) were much more able to answer a "collection" question (e.g., "Here is a family of frogs; this is the mother and this is the father frog, and these are the baby frogs, and this is the family. Who would have more pets, someone who owned the baby frogs or someone who owned the family?") than they were a typical class-inclusion question (e.g., "Who would have more pets, someone who owned all the frogs or someone who owned the little frogs?").

In a follow-up study, Markman et al. (1980) found that when information about the relationships among stimuli was ambiguous (the stimuli were line drawings of fictitious animals), children as old as 14 years tended to impose a collection, rather than a class, structure. How much the improvement is due to the greater psychological coherence of collections relative to classes is a matter of some debate (Hodges & French, 1988); however, the findings from Markman and Siebert (1976) regarding children's performance on class-inclusion problems are generally replicable by other researchers.

This all implies that understanding the relationships among different concepts is not simple. It also implies that relationships among subordinate-level, basic-level, and superordinate-level concepts (identified by Eleanor Rosch and discussed in Chapter 8) might not be easy to see or automatically understood. It also suggests that certain complex cognitive skills, such as reasoning, depend in complex ways on how knowledgeable children are about what is being reasoned.

Developing New Theories

S. Gelman and Kalish (2006) divide the theoretical approaches conceptual developmental researchers take into three categories. The first is a *nativist approach*, which holds that some concepts are represented, at least in part, innately. For example, we have previously seen that some researchers (e.g., Spelke, 2000) believe that children are born into the world with concepts such as *animism* or *causation*; others such as Fodor (1983) have put forward the idea that just about any concept that has a name (e.g., *zebra, comb, airplane*) must have innate representation. R. Gelman's (2002) proposal on children's skeletal principles of counting (discussed in Chapter 8) would fall into this camp as well. There is debate among different researchers in this camp as to whether specific concepts (e.g., for *zebra*) are innate or whether simply the tendency to pay attention to certain stimuli and not others is innate.

A second theoretical camp shares an *empiricist approach* to cognitive development, arguing that concepts are acquired either through direct representations of one's sensory or perceptual experience or by combining information from different sensory or perceptual experiences. Empiricist approaches, in other words, focus on information that is learned and ask questions about how children associate different experiences to form summary representations (S. Gelman & Kalish, 2006). For example, children are said to form concepts on the basis of similarity, grouping together instances on the basis of their overall surface appearance (e.g., Sloutsky, Kloos, & Fisher, 2007).

The third camp, the one that S. Gelman and Kalish (2006) advocate, is called the **naïve theory approach**. It holds that children construct commonsense understandings or theories that have individual concepts embedded in them, and whatever concepts are acquired at any point in development are constrained by the existing knowledge base. Said another way, the idea is that children acquire concepts mainly by relating new knowledge to the knowledge they already have.

Susan Carey (1985, 2000b) offers an example of this third approach in talking about children's developing knowledge of biological concepts. We began looking at this topic in Chapter 8 when we discussed preschoolers' understanding of biological concepts. Carey argues that children's understanding of what a living thing is undergoes tremendous change between the ages of 4 and 10:

> It seems unlikely that preschool children who insist that cars are alive could have the same concept of life as the adult and merely be mistaken about cars, and indeed, they do not. Rather, preschool children have constructed a very different theoretical framework from that held by adults in which they have embedded their understanding of animals, just as children of elementary school age have constructed a different framework theory in which they embed their understanding of the material world. These beliefs of young

> children are true beliefs, formulated over concepts that differ from those that underlie the intuitive or scientific theories that adults use to understand the world. (Carey, 2000b, p. 15)

Photo 10.1 A trip to the zoo allows children to expand their knowledge base about different animals.

Carey (1988, 2000b) argues that preschoolers have concepts of animals and people that are organized very differently from the way adolescents and adults organize these concepts. Preschoolers, Carey claims, understand what an animal is by making analogies to people. So they make analogies and understand animal behavior, physiology, and relationships by invoking what they know about human behavior, physiology, and relationships. Mother animals take care of baby animals in similar ways used by human mommies toward their babies, in the children's minds. Animals are judged to have internal organs by projecting from what the child knows about a human's internal organs. Said a little more succinctly, Carey holds that preschoolers view humans as the prototypical animal.

Carey notes then that children face a challenge as they acquire biological information over the course of their elementary years. They must not only learn new information, but they must reorganize their conceptual information, giving up the idea that humans are at the center of the biological universe! The average 10-year-old, according to Carey (2000b), has constructed a new theory—putting animals and plants together into the category *living thing*—that does not place humans as the central prototype.

S. Gelman and Kalish (2006) point out that the naïve theory approach necessarily incorporates aspects of the two other theoretical camps. The approach assumes the existence of some innate framework (nativist approach) that gives infants and children some direction as they learn new information (empiricist approach) and form new concepts. The emphasis of the naïve theory approach, however, is that children revise their conceptual organization as they acquire more information. The analogy made is to scientists, who periodically need to reorganize their concepts and understandings as new revolutions in knowledge occur.

Waxman, Medin, and Ross (2007) conducted a study with roots in the naïve theory tradition, albeit one that differed from Carey's. They believe that children have skeletal biological principles (akin to the skeletal mathematical principles discussed in Chapter 7) that change as children acquire more information. In particular, they focused on children's understandings of how it is that an animal comes to be a member of one species rather than another.

Waxman et al. (2007) interviewed children (aged 4–10 years) and adults from four different communities: rural Native Americans (from the Menominee tribe in Wisconsin), members of the rural majority culture from the same part of Wisconsin, and members of suburban and urban North American communities. Participants were questioned about various interspecies adoption scenarios. These included the following pairs: turtle–toad, cow–pig, and pigeon–turkey. For each participant, the animal designated as the birth parent and adoptive parent was determined randomly. For example, the following scenario refers to a baby cow, adopted and raised by pigs. The scenario was presented to participants orally as follows:

> I'm going to tell you a story. One day a cow gave birth to a little baby. Here's a drawing of the cow that gave birth to the baby [drawing of cow is shown]. Right after the baby was born, the cow died without ever seeing the baby [drawing of cow is removed]. The baby was found and taken right away to live with pigs in a place where there are lots of pigs. Here's a drawing of the pig [drawing of the pig is shown] that took care of the baby the whole time that the baby was growing up [drawing of pig is removed]. The baby grew up with pigs and never saw another cow again. Now the baby is all grown up, and I'm going to ask some questions about what it's like as an adult. (Waxman et al., 2007, p. 298)

Interviewees were then asked about various traits or behaviors that the biological and adoptive mothers had and asked to predict what the baby would do or have when it was grown, as in, "The cow mooed and the pig oinked. When the baby is all grown up, will it moo like a cow or oink like a pig?" and "The cow's heart got flatter when it sleeps, and the pig's heart got rounder when it sleeps. When the baby is all grown up, when it sleeps does its heart get flatter like the one of the cow or get rounder like the one of the pig?" (Waxman et al., 2007, p. 298). Table 10.1 presents a complete list of the behaviors, physical properties, and target animals included in the interview.

The results of the study showed that, among all four populations studied, interviewees believed that the baby would resemble the birth parent more than the adoptive parent. This tendency rose with age and was stronger for physical traits than for behaviors, especially for novel behaviors. Interviewees were also asked to say what kind of animal the baby was when it grew up—in our example, either a cow or a pig. Overwhelmingly, the interviewees chose the biological parent's species as the species of the baby.

Table 10.1 Experiment 1: Properties associated with the cow–pig, pigeon–turkey, and turtle–toad scenarios

Target Animal	Familiar Behavior	Novel Behavior	Familiar Physical	Novel Physical
Cow	Moos	Looks for sparrows	Straight tail	Heart gets flatter when it's sleeping
Pig	Oinks	Looks for cardinals	Curly tail	Heart gets rounder when it's sleeping
Pigeon	Very used to flying	Stops when it sees a maple tree	Short neck	Stomach gets harder when it's sleeping
Turkey	Very used to walking on the ground	Stops when it sees an oak tree	Long neck	Stomach gets softer when it's sleeping
Turtle	Walks slowly	Opens its eyes when it's afraid	Shell on its back	Blood becomes thick and sticky when it's sleeping
Toad	Hops	Closes its eyes when it's afraid	Warts on its back	Blood becomes thin and watery when it's sleeping

SOURCE: Waxman, Medin, and Ross (2007, p. 299).

NOTE: Novel behavioral and physical properties were counterbalanced across species.

Finally, interviewees were given a scenario of a blood transfusion, which was presented as follows:

> When the baby was growing up, it became sick. A doctor came and, with a needle, took out all of the old blood that the baby got from its mother [drawing of the birth parent is shown] when it was born. The doctor then went to the animal taking care of the baby [the drawing of the adoptive parent is shown] and took some of its blood to give to the baby. So the baby got all new blood like the blood of the pig. (Waxman et al., 2007, p. 299)

The purpose of presenting this scenario was to see whether participants believed that the mechanism of one's *kindhood*—that is, the species to which an animal belonged—would be seen as determined by its blood.

Previous research had shown cross-cultural differences in response to such a scenario, with Mayan children and adults not regarding blood as providing the "essence" of specieshood (Atran et al., 2001), but Brazilian children thinking that a blood transfusion could affect the species to which an animal belonged (Sousa, Atran, & Medin, 2002). Indeed, the Menominee population studied by Waxman et al. (2007) was an interesting one to include because some tribal rights and membership were in fact based on blood quantum requirements (i.e., what percentage of "Menominee blood" an individual had was determined by the parental enrollment in a Menominee tribe).

Results showed that the Menominee children were indeed more likely to consider blood as a mechanism that established an animal's species. The authors argue, "In a community in which discourse about blood is salient, and in which issues concerning blood have strong consequences, children seize on blood as a candidate biological essence and consider its potential in the transmission of kindhood" (Waxman et al., 2007, p. 300). Adult Menominee respondents responded differently and in line with the responses of the majority culture adults and children. The point here is that at least some children appear to form their theories of what instances (e.g., individual animals) belong in which categories (e.g., species) somewhat differently than do adults and that, as they acquire new information, those theories undergo change—sometimes change of a dramatic nature.

Kristi Lockhart and colleagues (Lockhart, Keil, & Aw, 2013a) recently completed a study that extends our understanding of children's essentialist views of different traits. They read children (aged 5–6, 8–10, 11–13) and adults stories about children who either had "natural" or "acquired" abilities, such as the one shown in Box 10.1. They wondered whether or not traits that occurred "naturally" would be seen as better than those acquired through different routes—such as through effort, through being bribed/rewarded/paid, or through taking medicine.

Box 10.1 Example of stories used in Study 1

Intelligence. When John was 5, he had a lot of trouble learning and remembering things compared to other children his age. Bill, on the other hand, could learn and remember things really easily. It hardly took him any effort to do well in school. Bill was naturally a good student.

(Continued)

(Continued)

When John was 10, he still had a hard time learning and remembering things compared to other children in his class. When Bill was 10, he was still able to learn and remember things very well. It was easy for him to do well in school.

Effort. John wanted to do better in school. So from the time he was 10 until he was 18, John decided to try really hard to be better at learning and remembering things. He worked hard to do better in school and put in a lot of effort. He wanted to be as good a student as Bill.

Bribe. John's parents wanted him to be better at learning and remembering things in school. So from the time John was 10 until he was 18, his parents rewarded him with money for working at being a better student. Because his parents paid him, John worked hard to learn and remember things better. John's parents wanted him to be as good a student as Bill.

Medicine. John wanted to be better at learning and remembering things in school. So from the time he was 10 until he was 18, John took some medicine to help him learn and remember things better. John wanted to be as good a student as Bill.

Now both Bill and John are older, 18. They are both good students. They do equally well in school. John (works really hard, or works really hard because his parents pay him money, or takes medicine) to be a good student and Bill naturally is a good student, doing well in school comes easily for him.

Questions

Strength. Suppose one of the boys is actually just a bit better at learning and remembering things than the other—just a pinch better at doing well in school. Who do you think would do a bit better at school? Why?

Reward. The school is giving prizes for the best students. The school knows that Bill is naturally a good student and that John (worked hard, or worked hard because his parents paid him money, or took medicine) to be a good student. Both Bill and John get prizes. (The order of character names was alternated across participants). One gets a big trophy, and the other gets a smaller trophy. Who do you think will get the bigger prize? Why?

Friend. With whom would you most like to be friends?

Change in Character. John had a hard time learning and remembering things when he was 5 and 10. Then John (worked hard, or worked hard because his parents paid him money, or took medicine) to be a good student. By the time he was 18, John was a very good student. Now that John is a good student, you ask his friends who have known him since when he was 5 and 10 whether he is the same person he was before. Everyone agrees that John is: (1 = the same to 5 = very different).

Persistence. Twenty-two years go by, and Bill and John are both older. When Bill and John were 18, they were both good students. John (worked hard, or worked hard because his parents paid him money, or took medicine) to do well in school and Bill naturally did well in school, but they both were very good at learning and remembering things. Now they are older, 40 years old (about the same age as your parents) and are working for the same company. At their jobs, both Bill and John have to learn and remember lots of new things. One of them is much better at remembering and learning new things than the other. Who do you think is much better at learning and remembering things now at age 40? Why?

SOURCE: Lockhart, Keil, and Aw (2013b, pp. 2–3).

Lockhart, Keil, and Aw (2013a) found that all age groups except 8- to 10-year-olds showed a preference for naturally emerging traits over acquired ones, even if the emergence of the trait happened late in development (e.g., was "late blooming"). That is, naturally emerging traits were seen as stronger, more deserving of rewards or recognition, more desirable in a friend, and more likely to persist. The authors believe that natural traits are perceived as fixed essences. The authors speculate that the more positive responses to acquired traits among 8- to 10-year-olds might reflect "the enormous emphasis many elementary schools put on effort," but that with maturity, older children come to "see through" this presentation.

HIGHER-ORDER COGNITIVE SKILLS

Higher-order cognitive tasks typically include reasoning, decision making, problem solving, and thinking. In each of these tasks, the information that has been previously received, processed, and stored by basic cognitive processes gets used, combined, reformatted, or manipulated by higher-order cognitive processes. We will focus on just a few of the possible set of higher-order cognitive tasks, given space constraints on the book and time constraints on the student reader!

Reasoning

In Chapter 8 we saw that, at least under certain circumstances, preschoolers could reason, both *deductively* (drawing conclusions that go from the general to the specific) and *inductively* (going from the specific to the general). Specifically, young children performed better when asked to reason about information they were very familiar with, or else when the premises presented information about a fantasy world, which presumably cued the children not to rely on their world knowledge.

Deanna Kuhn (1977) performed one of the classic studies on reasoning in middle childhood. She worked with children aged 6 to 14 years, giving them a series of **conditional reasoning** problems. Conditional reasoning problems come in four basic forms, as shown in Table 10.2. Only a brief review of these is possible here, but any text in logic (e.g., Skyrms, 2000) would provide more details.

Conditional reasoning problems begin with *premises*, or given information that is assumed to be true. One premise common to all four forms is, "If *p*, then *q*," often written symbolically as $p \rightarrow q$. The symbol *p* in the expression p → q is called the *antecedent*, and *q* is called the *consequent* of that particular premise. According to *propositional logic* (Skyrms, 2000), p → q is true whenever the antecedent is false or the consequent is true. Alternatively, we could say that p → q is false only when *p* is true and *q* is false. Thus the sentence, "If the second ice age started in 2000 CE, then my dog is a poodle," is automatically true (even though all of my dogs have been Bernese mountain dogs) because the antecedent ("the second ice age started in 2000 CE") is false (I like poodles, though; someday, I think I'll get one).

Notice that in logic, no cause-and-effect relationship must be present or is even implied. This contrasts with English because we normally expect the antecedent (what precedes) to be related to the cause of the consequent (what follows) when we use the expression, "If . . . , then. . . ." Also, when using the English expression, we consider, "If *p*, then *q*," to be false if *p* is false and *q* true (unlike in logic, where it would be considered true).

Table 10.2 Conditional reasoning problems

	Antecedent (IF—Part of the Premises)	Consequent (THEN—Part of the Premises
Affirmed (claimed to be true)	Modus ponens (valid)	Affirming the consequent (invalid)
Denied (claimed to be false)	Denying the antecedent (invalid)	Modus tollens (valid)

Two well-known rules of conditional reasoning are *modus ponens* and *modus tollens,* both shown in Table 10.2. Both are valid rules of reasoning, which basically means that if the premises are true the conclusions will also be true. Also shown in Table 10.2 are two other "rules" that turn out not to be valid; that is, they can produce conclusions that can be false even if the premises are true. "Rules" of this sort are called *fallacies*. Let's work through examples of why these rules are fallacies. Consider *affirming the consequent* as it applies to the following example: "If a person wears Birkenstock sandals, then he is a college professor. Roy is a college professor. Therefore, he wears Birkenstock sandals." Notice that the first premise ("If a person wears Birkenstock sandals, then he is a college professor") is not equivalent to the converse ("If a person is a college professor, then he wears Birkenstock sandals"). In fact, the first premise allows for the possibility of high-heeled professors (such as some of my more fashionable colleagues), which contradicts the conclusion.

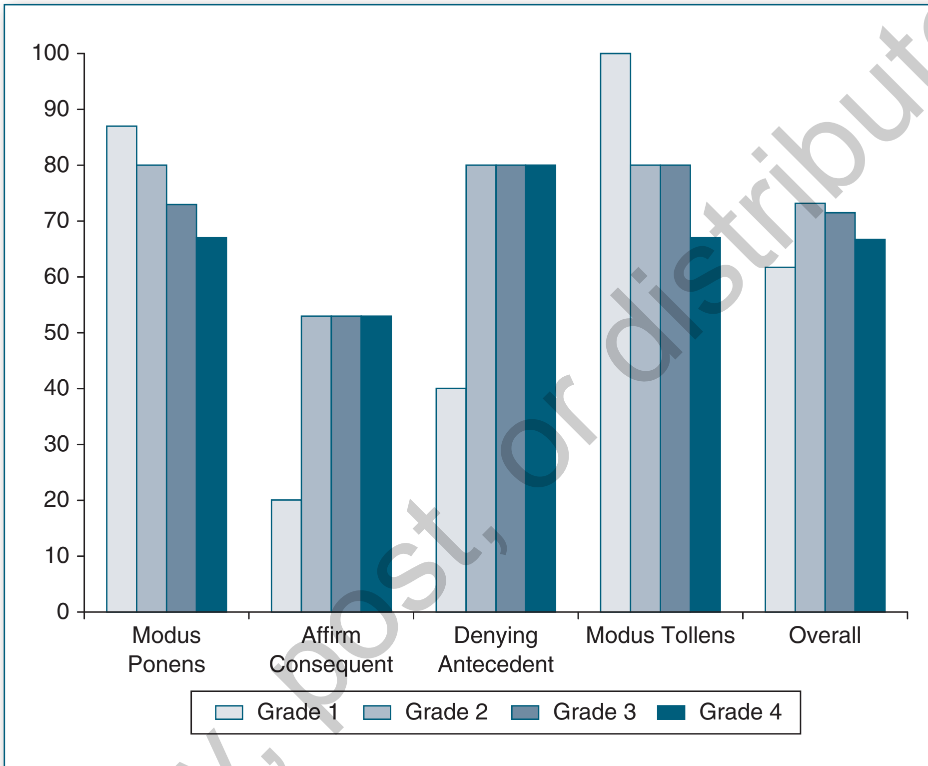
The second fallacy, *denying the antecedent*, is exemplified in the argument p → q: – *p,* therefore, – *q*. Using the example, these propositions would be instantiated as, "If a person wears Birkenstock sandals, then she is a college professor. Mija does not wear Birkenstock sandals. Therefore, she is not a college professor." For the reason just given (namely, the possible existence of high-heeled college professors), this argument is also false.

And now back to Deanna Kuhn's (1977) investigation of how children perform conditional reasoning. To engage children's interest and make the task more comprehensible, Kuhn told her participants about a fictional faraway city called "Tundor" and played a game where she would give them one piece of information about Tundor (e.g., "John is tall, and Bob is short") and then ask questions (e.g., "Is Bob tall?") to which the child could respond *yes, no*, or *maybe*. The pretest gave examples of questions that could be answered definitively as well as ones that could not, based on the given information. Only children who correctly answered both pretest questions were allowed to continue.

Next, Kuhn gave children each of the four conditional reasoning problems shown in Table 10.2. For example, a version of the modus ponens problem was, "All of the people in Tundor are happy. Jean lives in Tundor. Is Jean happy?" (The correct, logically valid answer is *yes*.) A version of the denying-the-antecedent problem might have been something such as, "All people who live in Tundor own cats. Mike does not live in Tundor. Does he own a cat?" (Here, the correct answer is *maybe*, as no logically valid conclusion can be drawn.)

Some of the results from Kuhn's experiment are presented in Figure 10.2. You can see that on these problems, even the first graders show some

Figure 10.2 Average percent correct by grade and conditional reasoning problem



SOURCE: Adapted from Kuhn (1977, p. 346).

reasoning ability, particularly on modus ponens problems. You can also see that children's performance varies dramatically as a function of the format of the problem (this is also true for adults; Markovits & Vachon, 1990). You might notice that with some problem forms there is a slight decline in performance for older students. Kuhn (1977) attributes this to the increased tendency for older children to respond *maybe,* even when a more definitive answer could be made.

Kuhn's use of the "cover story" about the land of Tundor presumably made it easier for children to understand the task she was posing to them. (You might recall from Chapter 8 that a study of deductive reasoning in preschoolers by Hawkins, Pea, Glick, & Scribner, 1984, used a similar technique.) Use of this cover story may account for the fact that children in her experiment performed much better than did children in earlier experiments given similarly structured problems with more abstract content (Byrnes & Overton, 1986; Ennis, 1975; Roberge & Paulus, 1971; Taplin, Staudenmayer, & Taddonio, 1974). Kuhn speculated that the ability to reason well with abstract formulations of these problems awaited attainment of the Piagetian stage of formal operations, an accomplishment typically seen in early adolescence.

Janveau-Brennan and Markovits (1999) round out this picture a little more. They worked with children aged 6 to 11 years, giving them conditional reasoning problems of the type depicted in Table 10.2. However, the content of the premises concerned so-called causal conditionals, statements that plausibly indicated a cause and effect. Some of the causal conditionals had relatively few easily imaginable alternative causes (the authors established this by having another group of children think of alternative causes). These included problems such as, "If a person goes to sleep late, he will be tired," and "If the electricity goes off, the school will be closed," where it had been established that children thought spontaneously of only a few alternative causes (e.g., other things that would cause the person to be tired or the school to be closed). They compared children's performance on these problems to their performance on problems where it was relatively easy to think of many alternative causes: "If a person breaks his arm, he will hurt," and "If a person drops a pot, there will be noise."

Table 10.3 presents the results by grade level of the children, both by the type of problem (again, refer to Table 10.2 for examples) and by the number of alternatives—few or many. It shows a consistent increase in correct responding (i.e., expressing uncertainty) to the two uncertain problems, affirming the consequent (AC) and denying the antecedent (DA). Somewhat paradoxically, there was a slight decline with age in responding correctly to the two forms that have valid conclusions, modus ponens (MP) and modus tollens (MT). The authors believe that as children get older, they become more able to generate alternative causes and to imagine "disabling" conditions for a conclusion. Thus, given the problem, "If the electricity goes off, the school will be closed," and "The electricity goes off," older children are more likely to think of possibilities such as the existence of emergency backup generators. This imagination, while normally serving the students well, does lead to incorrect performance in some cases.

As predicted, children performed better on problems where many alternative causes existed than they did on ones where few alternatives existed. This result replicated the findings of Cummins (1995) who had discovered this trend in adult participants. Janveau-Brennan and Markovits (1999) conclude that children are likely reasoning in ways fundamentally similar to the way adults reason, at least by the time they are in middle

Table 10.3 Percentage of correct responses to the four logical forms (MP, MT, AC, and DA) by grade level for premises with few possible alternatives and with many possible alternatives

Grade	Logical Form							
	MP		MT		AC		DA	
	Few	Many	Few	Many	Few	Many	Few	Many
1	78.1	97.3	82.3	88.2	10.4	17.3	7.3	4.6
2	76.0	99.0	88.0	93.3	19.0	40.4	10.0	16.4
3	68.8	100.0	88.5	93.9	34.4	49.1	14.6	13.2
5	57.3	98.1	75.0	84.9	55.2	82.1	29.2	50.9
6	51.0	94.9	72.1	87.8	64.4	82.7	42.3	44.9

SOURCE: Janveau-Brennan and Markovits (1999, p. 907).

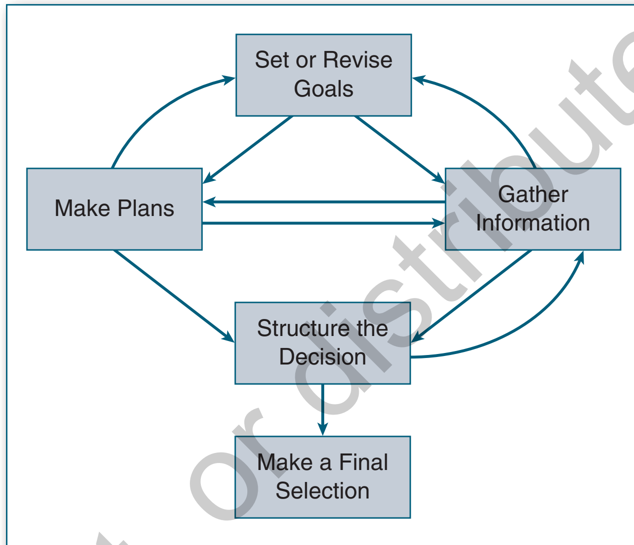
NOTE: MP = modus ponens; MT = modus tollens; AC = affirmation of the consequent; DA = denial of the antecedent.

childhood, and when they are reasoning with the kind of concrete, specific content given in these particular problems.

The authors also looked at whether children's reasoning performance varied as a function of their ability to imagine alternatives. They had asked the children to generate as many alternatives as they could in 30 seconds to two other causal statements: "If someone takes a bath, then she will be wet," and "If someone plays the flute, then there will be music." In other words, for each of these two statements, children were given 30 seconds to think of and name alternative ways of getting wet or making music. The mean number of alternatives generated rose steadily with age, with 6-year-olds able to generate 6.43 and 11-year-olds able to generate 11.72. More important, children who generated more alternatives were the ones who performed the best on the reasoning tasks, particularly on the uncertain AC and DA problems.

Markovits, Fleury, Quinn, and Venet (1998) conclude on the basis of these results and others that the basic processes of reasoning that adults use are in place by middle childhood, especially by about second grade (see also Evans & Perry, 1995). What changes with development, then, is the efficiency and speed with which reasoning processes are executed—an idea we discussed at length in Chapter 8. Changes in the central executive mean that it requires less cognitive effort to draw conclusions, so they are drawn faster and more efficiently. In turn, this allows more resources to be devoted to other tasks, such as thinking of alternatives, which may allow reasoners to "catch" themselves from drawing a faulty conclusion.

Figure 10.3 Phases of decision making



SOURCE: Galotti (2002, p. 97).

Decision Making

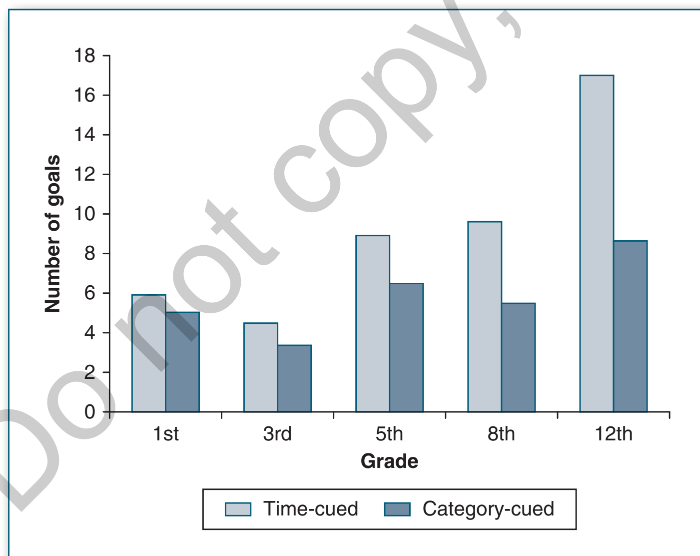
The task of decision making requires assessing and choosing among alternatives in terms of their probability of occurrence and their expected value. This assessment and consideration may be explicit and complex or implicit and rapid, but without consideration of alternatives, no decision making can be said to have taken place. Many models of decision making exist; the one I will use includes five phases: setting goals, gathering information, structuring the decision (i.e., enumerating both options and criteria for deciding among those options), making a final choice, and evaluating the decision (Galotti, 2002). This model is depicted in Figure 10.3. The term *phases of decision making* is used to convey the idea that there may or may not be a set order to the tasks, that the performance of one task can overlap with the performance of another, that some tasks can be skipped, and that tasks can be done in different orders.

Goals are things that guide decision making and that especially influence the way a decision maker will appraise options or prioritize criteria. *Information gathering* refers to the processes by which a decision maker constructs lists of options, as well as possible criteria to use in making his choice. For complex decisions with many alternatives and/or many criteria, decision makers need a way of organizing all their information. This phase of decision making, wherein the decision maker finds ways of organizing and comparing information, is known as *decision structuring*. After gathering all the information he is going to use, the decision maker needs to make a *selection or choice* from among the final set of options. This may involve a procedure as simple as flipping a coin or throwing a dart at a wall, or it may be considerably more complex.

With that brief overview in mind, let's turn to an examination of how children make decisions. Let's first consider the phase of goal setting. This phase has been seen as a very important one for making good decisions. Byrnes (1998), for example, argues that "self-regulated" decision makers, those who make decisions that advance their own interests, are those who behave rationally. Or as Miller and Byrnes (1997) put it: "A minimum requirement for being successful in life is knowing how to accomplish one's goals" (p. 814).

How does goal setting change with development during middle childhood? A few years ago, some students and I surveyed first, third, fifth, eighth, and 12th graders, asking them to report on their goals for the upcoming day, week, month, year, and lifetime (Galotti, 2005). When the participants ran out of goals to list, we switched to cueing them by category of goal—for example, "Do you have any school- or camp-related [the data were gathered over the summer] goals? Any family-related goals? Any goals related to your friends?" We called the first kind of goal "time cued" and the second kind of goal "category cued."

Figure 10.4 Number of goals by cue and grade



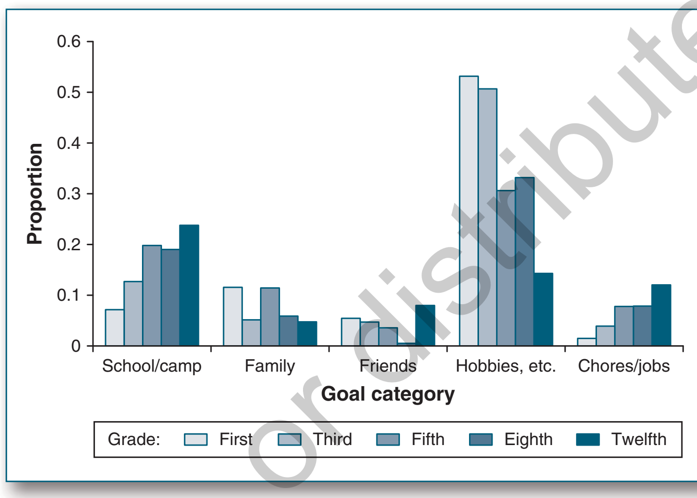
SOURCE: Galotti (2005, p. 313).

We found that, as shown in Figure 10.4, older students had more goals than younger students, particularly for the more open-ended time-cued goals. Moreover, older children reported a different "mix" of goals than younger children—goals related to hobbies and leisure activities became relatively less frequent, and goals relating both to school and camp and to chores and jobs became more frequent with age. Goals that pertained to either family or friends showed about the same proportion of use among all age groups, as shown in Figure 10.5.

Research assistants rated each goal listed for complexity (having lots of parts or subgoals), difficulty (degree of effort required to achieve the goal), specificity (how clear it is when the goal has been achieved), controllability (degree to which the achievement of the goal is under the sole control of the participant), and realism (plausibility that the goal can be achieved). We found that rated complexity and difficulty rose with age but that specificity and realism ratings were unrelated to age. Controllability ratings rose with age for time-cued but not category-cued goals.

In sum, then, older children reported having more goals; a higher proportion of goals having to do with school, work, or chores; and more complex and difficult goals than did younger children. One might assume that this complexity would put more constraints on decision making, but that relationship has yet to be explored.

Figure 10.5 Percentage of time-cued goals by category and grade

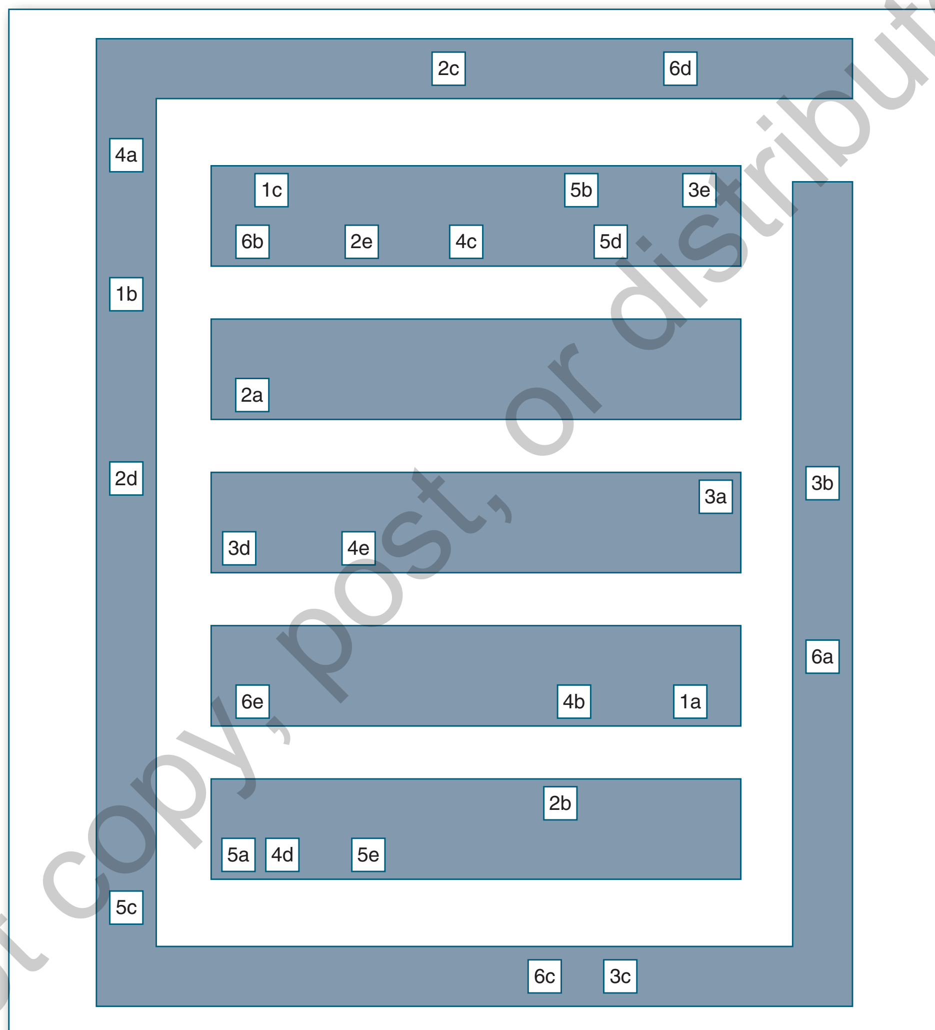


SOURCE: Galotti (2005, p. 316).

Planning is another aspect of decision making depicted in Figure 10.3. This is a relatively understudied topic in developmental psychology, but there are a few classic exceptions. A study by Mary Gauvain and Barbara Rogoff (1989) provides one illustration. They defined *planning* as "the process of devising and coordinating actions aimed at achieving a goal and of monitoring the effectiveness of the actions for reaching the goal as the plan is executed" (p. 140). To study this process, they devised an errand-planning task in a model (roofless) grocery store. Inside this (heavy cardboard) store were 160 grocery items depicted on 14 "shelves" of groceries. Figure 10.6 provides a representation of the spatial layout of the "store."

Children received "grocery lists" consisting of five items and were asked to send a "shopper" (a small, plastic figurine) to travel through the "aisles" of the store (without "flying" across the aisles) to fetch groceries. The shopper's trip always had to begin and end at the "door" of the store, and children were instructed to "help the shopper get the items on each list in the best way that they could." Experimenters coded the children's responses to see if they scanned the shelves in advance of moving the shopper through the aisles and to see if they made any comments describing the "efficiency"

Figure 10.6 Map of grocery store used in Gauvain and Rogoff's (1989) study; numbers and letters refer to "grocery list items" participants were asked to search for



SOURCE: Gauvain and Rogoff (1989, p. 141).

of a route through the store (e.g., reordering the list so as to minimize the number of trips down aisles).

Older children (aged 9) showed more advanced scanning than did 5-year-olds. Younger children (aged 5) used routes that were 2.6 times the length of the "optimal" route (determined in advance by the experimenters);

for the older children, their routes were only 1.5 times the length of the optimal one. The tendency to scan the store in advance correlated strongly with the efficiency of the route planned.

In a subsequent study, Gauvain and Perez (2005) found that real-world planning by children also undergoes development during the period of middle childhood. They surveyed 140 children who were all second graders at the start of the study and followed them for 3 years, examining how the children and their parents planned activities outside of the school day. They included both organized activities (e.g., dance lessons, choir, sports teams) and informal activities (e.g., watching television, playing video games, "hanging out"). They found that, as children grew older, they participated more in planning these activities, although the exact pattern of participation depended on the child's age, ethnicity, and gender, as well as the type of activity and the expectations of the parents.

Much more work has been done on children's *gathering information* phase of decision making. It has been shown in research on adult decision making that many adults use **heuristics** (shortcuts) and **biases** in their reasoning. For example, consider the following problem:

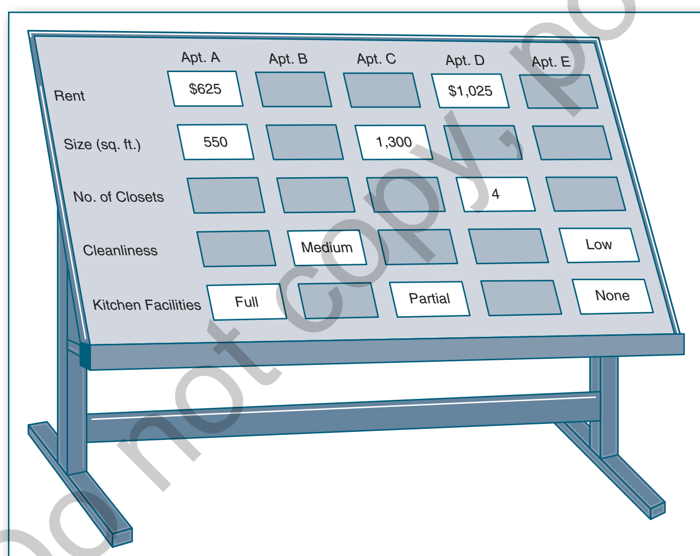
> Jim is buying a bicycle. Before buying it, he gets information on different brands. A bicycle magazine says that most of their readers say the Zippo bike is best; however, he speaks to his neighbor and she says that the Whammo bike is best. Which bike should Jim buy? (Jacobs & Potenza, 1991, p. 169)

Psychologists Amos Tversky and Daniel Kahneman, in a series of landmark studies, showed that adults were likely to use something they called the *representativeness heuristic* to choose an answer, rather than going through the laborious calculations it would take to calculate exact probabilities. Briefly, the representativeness heuristic causes people to focus on the overall similarity of a description to a stereotype without taking other factors into account (Kahneman, 2011). Kahneman and Tversky (1972, 1973) found, for example, that people typically ignored *base rates*—that is, responses collected from large samples—and instead disproportionately (and sometimes irrationally) paid too much attention to anecdotal information about one or two cases. Put in terms of the example above, adults would be more likely to ignore the recommendations of the bicycle magazine, which is based on the experience of hundreds or thousands of readers. Adults would instead give the majority of their attention to the recommendation of the one neighbor and her individual experience.

Comstock/Stockbyte/Thinkstock

Photo 10.2 Jacobs and Potenza (1991) studied the way children use information in making decisions, such as the purchase of a new bicycle.

Figure 10.7 Depiction of an information board



SOURCE: Galotti (2008, p. 487).

Jacobs and Potenza (1991) argued that in order to use the representativeness heuristic, children have to be able to compare information about a specific case (e.g., the neighbor's experience) with that of its representative category. They presented problems such as the one above to children in Grades 1, 3, and 6 as well as college students. The use of the representativeness heuristic rose with age. Younger children were more likely to offer idiosyncratic reasons for their choices or to "embellish" the stories with their own interpretations; sixth graders and college students were more likely to offer "textbook" representativeness explanations for their choices. Other studies suggest that as children get older, their estimates of base rates become more accurate and accessible (Jacobs, Greenwald, & Osgood, 1995). Relatedly, older children have acquired more social stereotypes and are more likely to use these when making decisions (Davidson, 1995).

Davidson (1991) devised a different way to examine how children gather information in making decisions. Figure 10.7 presents an information board used in adult studies of decision making (Payne, 1976). In this particular example, the decision to be made was to choose an apartment from among five options; information about each option was displayed in columns. There were five different kinds of information shown—rent, size, number of closets, cleanliness, and kitchen facilities. Research participants turned over one card at a time (e.g., rent for Apartment A), and the experimenter monitored how much information they gathered and how systematically they gathered it.

Davidson (1991) also used information boards, but she used bicycles instead of apartments. Table 10.4 shows the different kinds of decisions she presented and the information about each option in each decision. She found that second-grade participants examined more pieces of information than did older (fifth- and eighth-grade) children, but in a less systematic way, jumping from one dimension on one alternative to another dimension of information

Table 10.4 Examples of 3 × 3, 3 × 6, 6 × 3, and 6 × 6 information boards used in the Davidson (1991) study

Dimensions	Size of Bike	Price of Bike	# Friends Have Bike	Special Features	Old/ New	Color
			3 × 3			
Bike S	Just right	Lots of money	None			
Bike T	Just right	Little money	Many friends			
Bike W	Too small	Little money	Many friends			
			3 × 6			
Bike P	Too small	Little money	Some friends	Some	Old	White
Bike Q	Too big	Some money	Many friends	Lots	New	Blue
Bike R	Just right	Little money	Many friends	Lots	New	Red
			6 × 3			
Bike G	Just right	Lots of money	None			
Bike H	Too small	Little money	Some friends			
Bike I	Too big	Little money	Many friends			
Bike J	Too big	Some money	Some friends			
Bike K	Too small	Lots of money	None			
Bike L	Just right	Little money	Many friends			

(Continued)

Table 10.4 (Continued)

Dimensions	Size of Bike	Price of Bike	# Friends Have Bike	Special Features	Old/ New	Color
6 × 6						
Bike A	Just right	Lots of money	Many friends	Some	New	White
Bike B	Just right	Little money	Many friends	Lots	New	Red
Bike C	Just right	Some money	Some friends	Some	New	Green
Bike D	Too big	Little money	None	Some	Old	Black
Bike E	Too small	Lots of money	None	None	Old	Blue
Bike F	Too big	Little money	Some friends	None	New	Yellow

SOURCE: Galotti (2002, p. 107).

NOTE: The identical information was used to describe combs. From "Children's Decision-Making Examined With an Information-Board Procedure," by D. Davidson, 1991, *Cognitive Development, 6,* p. 81. Copyright 1991 by Elsevier Science. Reprinted with permission.

with another alternative. Older children were more likely to quickly eliminate alternatives (e.g., rejecting all bikes that cost "lots of money" or bikes that were too big or too small). In this respect, older children's performance was closer to that seen in adults (Payne, 1976), who are likely to adopt shortcuts that limit the amount of information they have to keep track of in making a decision.

At first blush, many of the above findings seem to be suggesting that younger children fall prey less often to decision-making biases, which might in turn imply that they are better decision makers. However, closer inspection of the results seems to suggest that younger children are less systematic, more idiosyncratic, and less analytic than older children, and that while they do not use common adult biases, they are not making sound decisions. What changes with development seems to be the efficiency with which information is searched for and processed, as well as the number of different strategies children have available to bring to bear on the task. Necessarily, the efficiency leads children to adopt timesaving shortcuts, such as heuristics. However, there is increasing variability among children in their approach to judgment and decision-making tasks as they mature (Jacobs & Klaczynski, 2002). We'll discuss this idea in much more detail when we examine adolescent decision making.

APPRENTICESHIP AND GUIDED PARTICIPATION

Reasoning and decision making are two of the most easily recognized higher-order cognitive skills. And as we will see in the next section of this chapter, these skills are important in many academic realms. But not all children in the world attend Western-type schools, and in this section, we'll take a look at how higher-order cognitive skills develop in non-Western cultures.

We've already looked at a theoretical perspective that provides an important framework for this topic—that of Lev Vygotsky. Recall that Vygotsky held that development is determined by many factors, including the tools available in a culture as well as the social milieu in which a child functions. Vygotsky described the *zone of proximal development,* arguing that children develop through participating in activities that are just slightly out of their cognitive reach. Through the guidance of skilled peers, parents, teachers, and others, children observe new skills and begin to internalize them (Guberman, 1996; Rogoff, 1990).

Consider, for example, a child learning an ordinary household task, such as folding laundry or making a bed. At first, the child has no idea what actions to take or how to carry them out. Typically, a child learns the sequence of steps by performing the chore with an older sibling or parent, who guides the child's actions either verbally ("No, take the sheet by the corner") or physically (e.g., by placing her hands over the child's hands). After a few sessions of practice, the young child learns how to do the chore and may even advance to the point of doing the entire task independently.

Rogoff (1990) introduced the term **guided participation** to describe this process. Her idea was that children acquire knowledge and skill about cognitive (and other) tasks when they both participate in the activities (as opposed to simply observing them) and receive guidance from a skilled practitioner. The guidance helps build a bridge from the child's beginning level of knowledge of the task to a more advanced one. The guidance is likely to be more explicit and physical at the start and to fade as the child acquires more skill


Andrew Olney/Photodisc/Thinkstock

Photo 10.3 Learning to make a bed under the watchful eyes of an adult is one example of guided participation.

and understanding. Said another way, as the child gains practice and experience, she is granted increasing responsibility for carrying out the activity.

Rogoff and colleagues note a fundamental distinction between European American communities and others around the world when it comes to guided participation and apprenticeship. Many traditional communities do not segregate children from adults, affording children many opportunities throughout the day to observe and learn from adult activities (Mejia-Arauz, Rogoff, & Paradise, 2005; Morelli, Rogoff, & Angelillo, 2003). As a result, children can be regarded as *apprentices* to adults. They learn not from explicit explanation and lecture, but instead from participating, with observation, guidance, and feedback from their more skilled adult mentor. Although there is guidance, it is more informal and implicit than is the overt control typically exhibited by a classroom teacher. Children collaborate cooperatively instead of working individually.

Chavajay and Rogoff (2002) report on a study of Guatemalan Mayan mothers constructing a puzzle with their children. Participants were formed into groups consisting of two or more mothers and three related children, aged 6 to 12 years. They constructed a three-dimensional jigsaw puzzle. Some of the groups included mothers with very little formal schooling (0–2 grades). Mothers in other groups had 6 to 9 grades of schooling, while mothers in the last group had 12 or more grades of schooling (i.e., they were high school graduates or more). Mayan mothers with more grades of schooling were much more likely to structure the task hierarchically, suggesting that labor be divided and that different children assume different responsibilities and work on different parts of the puzzle. Mayan mothers with less education were more likely to engage in a more collaborative, fluid, coordinated way, with all members of the group engaged in the same part of construction. The authors conclude that both forms of learning may be beneficial in the acquisition of new skills and understandings.

● DEVELOPING ACADEMIC SKILLS

In the United States, middle childhood runs roughly from a child's first-grade (or perhaps kindergarten) year of school through fifth or sixth grade—a part of schooling we call "elementary" education (as opposed to middle school and high school, which comprise "secondary" education). During the elementary years, the educational focus is on developing literacies of various sorts—learning to read, learning to write, and learning arithmetic. In addition, children are expected to master content in areas such as social studies, science, and perhaps health, art, and music. In this section, we will focus primarily on the "3Rs" (reading, 'riting, and 'rithmetic).

Learning to Read

Learning to read is a task that consumes the bulk of the day in most kindergarten through second- or third-grade classrooms. The idea that spoken sounds correspond to written letters is often quite a concept to master, and the skills involved in the task of reading are many. In order to read a text, for example, a student must already understand how to hold a book or manuscript and which way the text goes (horizontally in English vs. vertically for Chinese, for example). She must also know the basic characters of the language and be able to decode letters into sounds. She must be able to recognize a number of "exception words" that do not follow the default spelling–sound rules of the language.

Jeanne Chall (1983) presented a stage theory of reading development, based on her work with children learning to read in the United States and her reading of Piagetian theory of cognitive development. She accepts the idea of stages building hierarchically and progressively upon one another. She believes that interaction with the environment—at home, at school, and in the community—contributes to the progression through stages. As readers progress through the stages, they become increasingly independent and intentional about their reading.

The first stage (Stage 0) is called "Prereading" and spans from roughly birth to age 6 years. During this time, the child develops the visual and auditory perceptual abilities that will later be used in reading (e.g., being able to discriminate between similar sounds) and might even begin to recognize certain letters or even certain words (e.g., the child's own name), assuming the child lives in a literate culture. Although I'm embarrassed to admit this, both of my children, when preschoolers, could recognize a variety of commercial logos—such as the ones for McDonald's, Applebee's, and (heaven help me) Chuck E. Cheese's. Chall would count all of this as a prereading activity. Prereading children may also engage in "pretend" reading, during which they hold a book and turn the pages, look at the pictures, and make up the "text" that goes along with the pictures (or recite the text from memory, in the case of a frequently read favorite).

Stage 1, "Initial Reading, or Decoding," occurs when most children are aged 6 or 7 and in first or second grade. It is during this stage when children learn the alphabet and the sounds corresponding to each letter or character. Chall (1983) calls this the "grunt and groan" or "barking at print" stage because reading is a laborious task for young children, who expend most of their energy on just decoding. If you've ever listened to a first grader read aloud to you, you'll understand why Chall came up with these descriptive names! The 6-year-old in this stage reads laboriously, one word at a time, with long pauses between words and not a lot of fluency or inflection.

Elementary school teachers working with beginning readers often note a dramatic shift occurring in reading—where the child suddenly seems to "get it" and the reading becomes more fluent. At this point, the child has entered Stage 2, which Chall (1983) titles "Confirmation, Fluency, Ungluing From Print." It typically spans ages 7 and 8, Grades 2 and 3. During this stage, children consolidate gains from Stage 1, become more fluent and expressive in their reading, and gain what Chall calls "courage and skill" in reading.

The stage is a critical one; students whose reading skills are below average at the end of third grade are at risk for school failure in the future. Stage 2 also represents the point at which campaigns to foster adult literacy fail; although most adults who are illiterate can make it through Stage 1, if they falter, the problem is likely to show up in Stage 2. According to Chall (1983), successful navigation of Stage 2 requires availability of familiar materials to read—most books, pamphlets, and newspapers require at least a Stage 3 reading level. Perhaps for this reason, reading skill gaps between high-socioeconomic-status and low-socioeconomic-status children widen during Stage 2. Presumably, wealthier families are more able to provide more readable materials to children in this crucial stage of reading development.

Stage 3, called "Reading for Learning the New: A First Step," corresponds to the later elementary and middle school years, Grades 4 through 8. It is during this stage that children start to read texts to get new information—that is, reading to learn instead of learning to read. Many so-called content areas of the curriculum (e.g., history, geography, health, and science) begin to be taught as separate subjects in the fourth grade, and from a reading perspective, this makes good sense. Much of the way students go about learning in these domains is through reading—textbooks or websites or workbooks. According to Chall (1983), even fourth-grade materials help the learner begin to master the ideas they present:

> The materials at the 4th-grade level and higher begin to go beyond the elemental, common experiences of the unschooled or barely schooled. To write out even the simplest informative materials—materials that present ideas that the reader does not already have—a readability level of at least Grade 4 is usually required. Materials at Grade 4 readability level begin to contain more unfamiliar, "bookish" abstract words (ones that are usually learned in school or from books) and a higher proportion of long and complex sentences. . . . While the learner is in the decoding (Stage 1) and confirming (Stage 2) stages, the task is to master the print; with Stage 3 the task becomes the mastering of ideas. (pp. 21–22)

Chall's (1983) final stages, Stage 4 and Stage 5, correspond to high school and college, respectively. Stage 4 has to do with reading a text from multiple points of view and dealing with layers of facts and concepts. Stage 5 concerns reading for one's own purpose—reading some texts closely and analytically, while skimming others only briefly.

Some controversy exists in the field of education over whether early reading should emphasize decoding (the so-called **phonics** approach) or instead focus mainly on meaning (the so-called **whole-language** approach; Chall, 1992; Pressley, 1994; Pressley, Mohan, Raphael, & Fingeret, 2007). The debate centers on whether explicit instruction in decoding is required for at least some students to learn the skill and, further, whether explicit instruction in decoding will undercut students' motivation for, and enjoyment of, reading.

Proponents of the whole-language approach advocate for surrounding children with good literature that engages their imagination. They see reading as mainly involving higher-order cognitive processes, such as making predictions and inferences, and assume that the lower-order decoding skills will naturally occur as children experience more literacy activities such as hearing stories, creating stories orally or in writing, and talking about stories.

Existing evidence in the psychological literature has not borne out these claims (Chall, 1992; Juel, 1988; Pressley, 1994). Indeed, one of the best predictors of reading achievement in the primary grades of school (Grades 1–3) is **phonemic awareness**, an ability to understand that words are composed of separable sounds. Typically, one important difference between good and poor readers at all age levels is that good readers have better phonemic awareness than do poor readers (Pressley, 1994) and are better able to categorize spoken words by their initial or ending sounds—that is, to find alliterating and rhyming words. Interestingly, a study by Evans, Fox, Cremaso, and McKinnon (2004) suggested that parents' lay views of reading were much more receptive to a phonics-based approach, while the teachers surveyed in this study were more likely to endorse a comprehension-based, whole-language approach.

A recent meta-analysis conducted by Galuschka, Ise, Krick, and Schulte-Körne (2014) examined the effectiveness of different methods of teaching reading to children and adolescents with reading disabilities (dyslexia). Essentially, a *meta-analysis* is a statistical summary of lots of other empirical studies, looking for consistent trends in findings and weighting the results by the sizes of the samples of participants used. They found that phonics instruction was "the only approach whose efficacy on reading and spelling performance in children and adolescents with reading disabilities is statistically confirmed" (p. 1).

Courtesy of Lucie Shipp Treddenick

Photo 10.4 Learning to read involves mastering a set of complex skills.

Michael Pressley and his students (2007) performed an in-depth observational study of a public elementary school in Michigan whose average scores on standardized tests of early literacy outperformed those of similar schools in the area and which was in the vicinity of the institution where Pressley worked. During the course of the yearlong project, the researchers interviewed the principal, teachers, and teaching interns and spent over 200 hours observing classrooms and staff meetings.

They found that a variety of factors were likely to have led to the school's success at promoting literacy. First, literacy was a core academic emphasis of the school, with many hours of teacher time devoted to it. The school was well stocked with books, and a variety of specialist teachers were available to supplement classroom teachers' efforts. Classroom teachers were committed to professional development and sought out opportunities to refine their skills in teaching reading and to better understand the structure and composition of the standardized tests. They incorporated phonics-based activities in many of their lessons in the lower grades, with increasing emphasis on sophisticated comprehension in the older grades. Children read aloud, with teachers listening, at least several times a week. Writing was also integrated into the literacy instruction from kindergarten. Pressley et al. (2007) concluded that, even in a suburban setting with relatively advantaged students, "great efforts may be required to produce high reading and writing achievement" (p. 221).

Learning to Write

Writing, like reading, is a complex skill. Early development of writing focuses on concrete issues, such as how to form letters correctly and conventionally when composing a message. We are all familiar with the handwriting charts such as the one shown in Figure 10.8. But teachers and researchers have described a number of stages that children's initial writing goes through before it reaches the maturity shown in Figure 10.8.

As we saw above with reading, writing is a subject children already know a great deal about by the time they get to school. Although they do not begin by writing words using the conventional spellings of the adults in their community, they still have a great deal of knowledge about what writing is. There is debate among early educators about how stagelike the

Figure 10.8 A chart showing how the letters of the alphabet are to be written

early development of writing is, and the description below is an amalgamation of different proposals. The essential point is that children's unconventional attempts at writing do show structure and reflect their growing understanding of what writing is (Feldgus & Cardonick, 1999; Paul, 1976; Read, 1971; Richgels, 2001; Vukelich & Golden, 1984).

Most children begin writing by drawing and *picture writing*. Often the pictures are unrecognizable, but the child can, when prompted, describe what the picture depicts. Although you might want to argue that this is art and not writing, it does represent the earliest attempt to communicate thoughts and feelings by making marks on paper. By about age 3 years, many children make a distinction between drawing and writing (Dahl, 1985; Vukelich & Golden, 1984).

This stage of writing is succeeded by the *scribbling* stage. Children make random marks on the page, where the starting point and ending points can be anywhere on the page. Over time, children learn to make

Figure 10.9 An example of writing in the random-letter stage (the embedded names are not typical of this stage)

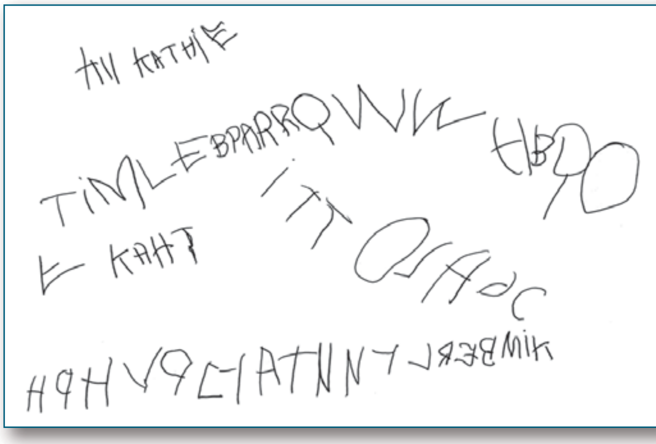
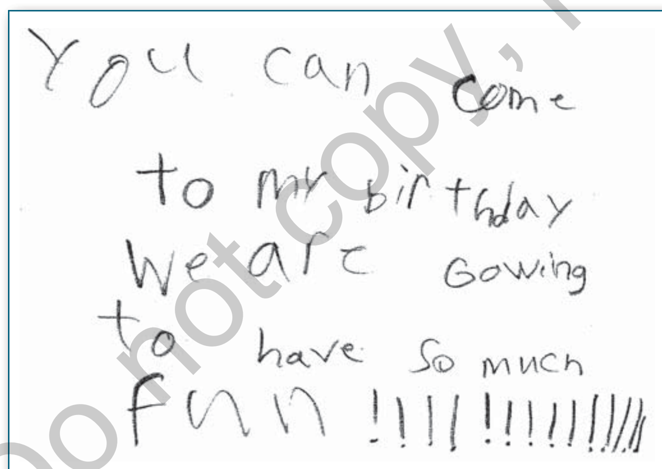


Figure 10.10 An example of transitional spelling



their marks in conventional directions (e.g., in U.S. culture, from left to right). Also occurring in the scribbling stage is the appearance of more recognizable shapes in pictures (e.g., stick figures of humans or animals, or a circle with lines surrounding it depicting a sun).

Next comes the *random-letter* stage. An example of this is shown in Figure 10.9 and is the production of my daughter during preschool. The letters bear little relationship to conventional spelling, but there are recognizable letters of the alphabet in the writing. At this stage, the child may be capable of spelling her own name correctly, and the spelling may even be correct. (In my daughter Kimmie's case, however, she began by signing all her artwork "Emily," which greatly puzzled me until I learned that she was copying an older preschool friend, whom she sat next to every day during art time.)

Semiphonetic spelling comes next. Some letters in the writing match sounds, and especially the initial letters may be correctly placed, even when sounds corresponding to the middle and ends of words are not presented. Next comes *phonetic spelling,* where both beginning and ending sounds appear, some high-frequency words are correctly spelled, and often vowels appear (even if they aren't the correct ones). *Transitional spelling,* as the name implies, brings a child closer to the stage of conventional spelling and writing. Children spell by sounding out the words and spelling more high-frequency words correctly, and they begin to leave spaces between words. They may also begin to incorporate some punctuation. Figure 10.10

provides an example. Note that the misspelled word *gowing* actually makes phonetic sense—it indicates that the child is making an attempt to translate the sounds she hears in a word into letters. If you say the word *going* aloud, you may hear a *w* sound in the middle!

Eventually, likely in the later primary grades (2 or 3), most children settle into *conventional spelling,* where most words are spelled correctly, especially short or high-frequency ones. Children still revert to phonetic spelling for unfamiliar words. Capitalization and punctuation are used correctly, and the child systematically uses both capital and lowercase letters.

Writing is intimately connected with reading, leading many researchers to speak of emergent literacy as a general term involving both (Teale, 1987). Indeed, the claim is that the development of reading influences the development of writing and vice versa. It's easy to see how this principle might apply to early stages of spelling, for example. To write words phonetically, a child must be able to hear the different phonemes in the spoken versions of the word, and as we have seen, phonemic awareness is a critical reading skill.

Empirical research has demonstrated that young children's writing proficiency is significantly predicted by early reading skills, including letter awareness (Dunsmir & Blatchford, 2004). A longitudinal study following 54 at-risk students from first through fourth grade examined reading and writing performance each year (Juel, 1988). The correlation between writing skill and reading comprehension was .27 in first grade, .39 in second grade, .43 in third grade, and .42 in fourth grade. Reading performance was a stronger predictor of writing performance than the converse. Moreover, and frighteningly, "The probability that a child would remain a poor reader at the end of fourth grade if the child was a poor reader at the end of first grade was .88" (Juel, 1988, p. 437).

The description of writing development just given focuses on early and concrete manifestations of writing—how marks are physically made and how children come to adopt standard ways of making them. But there is another, at least equally important component to writing—what Juel (1988) calls *ideation,* the ability to generate and organize ideas. This component has to do with how children create stories, essays, notes, memoirs, or other written products, focusing more on the text than on the spelling or penmanship.

We've seen already that young children know a lot about stories, even before they begin reading and writing. We saw in Chapter 7 the work by Katherine Nelson and her colleagues on children's scripts, which are organized schemas for representing event knowledge. We saw that children's scripts become more elaborate, organized, and hierarchical as they gain more experience with an event. Nelson (1986) saw scripts as the basis of children's autobiographical memories. Others have come to regard scripts as the basis of children's self-created stories (Mandler & Johnson, 1977).

Mandler and Johnson (1977) and Just and Carpenter (1987) are two sets of psychologists who developed the idea of *story grammars*. Story grammars are systems of rules that can "parse" a story into parts (just as a grammar for a language helps listeners and speakers parse the words into a known structure). Story grammars are similar to scripts in that both have *variables*, or slots that are filled in differently for different stories. For example, different stories have different protagonists, settings, plots, conflicts, and resolutions. Story grammars are also similar to syntactic grammars in that they help identify the units (constituents) and the role each unit plays in the story (Just & Carpenter, 1987).

Like other schemata, story grammars provide the listener or reader with a framework with which to expect certain elements and sequences and to fill in with "default values" things that are not explicitly stated. For example, young children expect stories to begin with some sort of setting, say, "Once upon a time," or "A long time ago." One example of a story grammar is shown in Figure 10.11 (Mandler & Johnson, 1977). It divides a story into several parts: settings, states, events, and so forth. Each of these parts may also have subparts—for example, settings may have location, characters, and time. Some parts may also have a number of different instances of certain subparts—for example, the plot may have several episodes. The asterisks in the table indicate that certain subparts (such as "state" in Rule 4) can be repeated an indefinite number of times. Parentheses around a subpart indicate the subpart is optional.

Children as young as 4 years of age have been found to recall stories better if those stories conform to a story grammar than if they do not (see Mandler, 1983), and in retelling the stories they've heard, 4-year-olds tend to recount the elements of the story in the "correct" story grammar order. Research investigating children's production of stories shows that, with age, children produce more elaborated stories, with more details given to such aspects of the story as setting, character motivation, and complexity of plot (Mandler, 1983).

During the elementary years, children begin to focus less on the "secretarial" aspects of writing (e.g., handwriting and spelling) and more on the "compositional" aspects of it (generating ideas and organizing them; Wray, 1993). Lin, Monroe, and Troia (2007) studied second through eighth graders' views of what "good writing" is. They found that younger students focused more on the physical aspects of writing—things like punctuation, using cursive, and having good posture—while older students focused on higher-level aspects, such as audience, meaning, and communication. Second graders described the process of writing as "just think about it" before

Figure 10.11 Summary of rewrite rules for a simple story grammar

FABLE → STORY AND MORAL

STORY → SETTING AND EVENT STRUCTURE

SETTING → { STATE* (AND EVENT*) / EVENT* }

STATE* → STATE ((AND STATE))

EVENT* → EVENT (({ AND / THEN / CAUSE } EVENT)) ((AND STATE))

EVENT STRUCTURE → EPISODE ((THEN EPISODE))

EPISODE → BEGINNING CAUSE DEVELOPMENT CAUSE ENDING

BEGINNING → { EVENT* / EPISODE }

DEVELOPMENT → { SIMPLE REACTION CAUSE ACTION / COMPLEX REACTION CAUSE GOAL PATH }

SIMPLE REACTION → INTERNAL EVENT ((CAUSE INTERNAL EVENT)).

ACTION → EVENT

COMPLEX REACTION → SIMPLE REACTION CAUSE GOAL

GOAL → INTERNAL STATE

GOAL PATH → { ATTEMPT CAUSE OUTCOME / GOAL PATH (CAUSE GOAL PATH) }

ATTEMPT → EVENT*

OUTCOME → { EVENT* / EPISODE }

ENDING → { EVENT* (AND EMPHASIS) / EMPHASIS / EPISODE }

EMPHASIS → STATE

SOURCE: Mandler and Johnson (1977, p. 117).

commencing—middle schoolers reported using more strategic planning activities, such as making outlines or using story webs. Older students were also more likely to differentiate between different types of writing (e.g., narrative, expository, and persuasive writing), while younger students showed less understanding of these distinctions.

McCutchen (2006), drawing on the work of Hayes (1996; Hayes & Flower, 1980), describes three major cognitive processes involved in writing. The first is *planning*—which may involve making notes, thinking about goals, generating content, and organizing it. Younger children are less adept at planning than are adult expert writers. For example, young children are less likely to make notes or revise the notes they do make when writing; they often begin a writing assignment by starting to write the text within a minute or two of receiving the assignment.

A second important cognitive process used in writing is *text production*—translating ideas into sentences and paragraphs (McCutchen, 2006). Essentially, children need to learn new schemas to generate text—they are used to creating spoken texts and now need to learn new schemas to generate written ones. In essence, children learning to write need to regard their written output as a kind of dialogue between themselves as writers and the reader(s) in their audience.

Finally, *revision* is crucially important, at least for good writing (as you already know from your college work!). Reviewing one's prose, reading it critically, and seeking feedback from others are all included here. Some work suggests that students with better writing skills focus their revision on issues of meaning and organization, while less skilled writers stay focused on the local level of individual sentences (McCutchen, 2006).

Writing is a complex skill that develops progressively over middle childhood and adolescence. According to Graham and Harris (2000; Graham, Harris, & Mason, 2005), it requires extensive self-regulation and attentional control—so that activities such as planning, generating sentences, and revising can be coordinated. As such, the executive functioning tasks we reviewed in Chapter 9 play an increasingly important role in writing as children progress through the elementary years.

Learning Math

In Chapter 8, we examined preschoolers' concepts about numbers and counting. We saw that, even before formal schooling begins, children have a number of implicit principles about how counting works. They know, for example, that each object or person to be counted should receive one count tag, that the same order of tags should be used on all occasions, and that the final tag represents the numerosity of the set of counted objects.

Children learn a lot more about math during elementary school. Not only does their counting become more conventional, but throughout the elementary school years, children learn facts about addition, subtraction, multiplication, and division. In the later elementary years (e.g., fourth through sixth grades), children begin to learn about complex arithmetic procedures, such as long division. In this section, we'll take a brief look at many of these academic achievements.

If you think back to your elementary math classes, you might recall a lot of "**drill and practice**" aimed at getting you to learn your basic math facts, including worksheets, computer games, flash cards, and "mad minute" tests such as that shown in Figure 10.12. You might have wondered then

Figure 10.12 Mad math minutes

Mad Math Minutes

Solve the following problems

11 + 1	17 + 8	20 − 6	18 + 3	20 + 18
5 + 3	9 + 0	12 + 3	16 + 6	12 − 4
15 − 5	18 + 3	5 + 0	19 + 12	8 − 5
19 + 18	10 + 1	19 + 7	19 − 9	17 + 6

Check My Answers   Reset

(or you might wonder now) what the point of it all is. Why is it important to compute sums such as $3 + 5$ or 7×9 in seconds or fractions of seconds?

If you think back to what we've talked about with respect to working memory, you'll understand. The answer has to do with capacity. The more that arithmetic facts are practiced, the more automatic it becomes to retrieve them. The more automatic the retrieval, the less capacity is used. The less capacity that is used, the more that is left over for other tasks or for more complicated tasks.

Consider, for example, a complex procedure such as long division. A student learning this method for the first time is going to have a lot to think about and remember. Put in cognitive terms, the process requires a great deal of attentional capacity. If the student needs to stop to compute a fact such as 7×9 in the middle of trying to carry out long division, the whole process might collapse. On the other hand, if arithmetic facts have become automatized, then retrieval requires little effort and happens quickly (Resnick, 1989).

However, the drill-and-practice approach is not the only one adopted by elementary teachers. Another approach, sometimes called "meaningful learning" (Resnick & Ford, 1981), emphasizes conceptual understanding of mathematical principles. This kind of approach, for example, might stress fostering understanding among children that, if $5 + 3 = 8$, then $3 + 5 = 8$ and, as well, $8 - 3 = 5$ and $8 - 5 = 3$. The emphasis here would be on getting children to see the principles that underlie these relationships instead of on speed of automatic retrieval. The argument is that children instructed with this approach will find it easier and more natural to apply their knowledge to new problems and situations.

Children's arithmetic strategies undergo a great deal of development during elementary school. Take, for example, addition. If you look at a typical 5-year-old trying to figure out what $3 + 5$ is, you might notice him counting on his fingers or perhaps putting up three fingers on one hand and five on another and counting the set. (This strategy runs into trouble, obviously, when one of the to-be-added numbers exceeds the number of fingers on one hand!) After entering school, most children are able to do "mental counting"—adding three and five by saying the count words without using fingers (Resnick, 1989). By around age 6 or 7, most children use a strategy psychologist Lauren Resnick (1989) calls "counting on"; as an example, she states what happens when the children are given the problem $5 + 3$:

> [They] behave as if they are setting a mental counter-in-the-head to one of the addends, and then count on by ones enough times to "add in" the second addend. Thus, to add 5 and 3, children might

> say to themselves, "5 . . . 6, 7, 8," giving the final count word as an answer. What is more, children do not always start with the first number given in a problem but will invert the addends to minimize the number of counts when necessary. Thus, in adding 3 + 5, they perform exactly the same procedure as for adding 5 + 3. Children's willingness, in a procedure they invent for themselves, to count *on*—without first counting *up* to the first number—demonstrates that they have come to appreciate that "a 5 is a 5 is a 5. . . ." In addition, children's willingness to invert the addends shows that they implicitly appreciate the mathematical principle of *commutativity* of addition. It will be some time, however, before they will show knowledge of *commutativity* in a general way, across situations, across numbers, and above all, with an ability to *talk about* rather than just *apply* the principle. (pp. 164–165)

A study by Holmes and Adams (2006) of British children aged 7 to 11 years showed a number of statistically significant correlations among children's mathematics measures (assessing such things as number knowledge, counting, geometric knowledge, interpreting graphs, and performing mental arithmetic) and various measures of different components of working memory. Even when controlling for grade in school and age, there were several significant correlations between the visuospatial sketch pad, the central executive (discussed in Chapter 9), and the mathematical measures. The phonological loop was less effective as a predictor of children's performance on mathematical assessments.

A recent study by Sidney and Alibali (2015) looked at older children's understanding of division by fractions (e.g., *2 ÷ 1/3*). As you might recall from late elementary or early middle school, this concept can be a slippery one for children to grasp. (The answer to the example, by the way, is *6*). Students who first practiced structurally similar math problems (e.g., whole number division, such as *36 ÷ 6*) were more likely to understand the concept of dividing with fractions than were students who first practiced with other mathematical operations on fractions. The authors point out that learning mathematics works best when children are guided through practice to make connections between existing concepts and new ones.

Children's development of mathematical knowledge in elementary school also varies as a function of their culture, as studies by David Geary and his associates have shown (Geary, Bow-Thomas, Liu, & Siegler, 1996; Geary, Salthouse, Chen, & Fan, 1996). One's native language can be a powerful factor in learning to count. For example, in the English language, the numbers in the second decade (especially *eleven* and *twelve*) do not make transparent the base 10 system. In contrast, Chinese number words for 11, 12, and 13 can be translated as *ten one, ten two,* and *ten three,* respectively—making it more obvious that 11 means one *ten* unit and one single unit.

Moreover, the English names *eleven, twelve,* and so forth take longer to pronounce than do the corresponding Chinese count words. As a result, English-speaking children can say fewer digits in a short amount of time than can Chinese-speaking children. When digit spans are measured in children in the two cultures, Chinese-speaking children show a significant advantage over English-speaking children, with Chinese children's digit spans an average of two more slots larger than American children's. Geary et al. (1996) used these findings to explain the fact that in their study, Chinese kindergarteners outperformed American kindergarteners on a test of simple addition problems in the fall of their first year of school. Moreover, by the end of that same year, the differences in performance grew greater. Similar patterns of initial difference followed by even greater subsequent difference were found for first, second, and third graders tested. The authors explain the greater gain for Chinese students in terms of the greater number of minutes specifically devoted to mathematics instruction in Chinese schools.

This research underscores the idea that academic skills such as arithmetic, reading, and writing are embedded in larger cultures, a very Vygotskian notion. The fact is that even supposedly abstract tasks such as addition take place in particular contexts, and aspects of those contexts, such as the language that is spoken, affect the way the task is carried out. Formal schooling is, of course, another important aspect of culture. As such, formal schooling has pervasive effects on the cognitive development of the children who attend.

Using Educational Apps

The last 5 years have seen a virtual explosion in the number of households that have either smartphones or tablet computers. "Apps," or applications developed for these devices, have been created to be used in educational settings across the United States. But are all educational apps created equal, and do they really promote reading? A recent review by Hirsh-Pasek et al. (2015) examines these important questions carefully.

The authors review decades of research in the science of learning and try to apply lessons learned to the evaluation of the educational value of particular apps. In particular, they describe four "pillars" of learning against which to evaluate the educational value of an app: "Research suggests that children learn best when they are cognitively active and engaged, when learning experiences are meaningful, and when learning is guided by a specific goal" (p. 4). By "cognitively active," Hirsh-Pasek and colleagues distinguish between apps that simply allow or require children to tap or swipe from those where children need to think or devote mental effort to the activity. By "engaged," they mean keeping a child focused on the task at hand and insulated from distractions. "Meaningful learning" refers to the process of connecting new information to knowledge already in one's storehouse of information. Having a specific learning goal is meant to differentiate between engaging (addictive?) game apps—think Candy Crush or Angry Birds—and those that promote actual learning.

Hirsh-Pasek et al. (2015) suggest that apps can be usefully incorporated into formal educational settings under certain specific conditions. For example, since a certain amount of drill and practice is needed to learn math facts such as multiplication tables, well-designed apps might promote effective engagement in what could otherwise be a dull and repetitive task. The authors caution, however, that having an app with too many bells and whistles might simply distract a student from the to-be-learned task or will overwhelm a child with too many choices or too many changes of presentation.

We've covered a lot of ground in this chapter. We've talked a lot about different kinds of higher-order cognitive skills, ranging from reasoning to decision making to planning to problem solving, and a variety of academic skills, such as reading, writing, and arithmetic. We have seen how the functioning of these higher-order skills can vary a great deal, depending on the context in which these skills occur. We have seen that much of cognitive development during middle childhood, particularly increases in attentional focus and working memory capacity, enables the growth of higher-order skills.

Middle childhood gives way to early adolescence, of course, and we'll see in the next two chapters how the cognitive processes described so far evolve during that developmental period. We will see specifically in the remaining chapters that the refinement of higher-order cognitive skills comprises much of cognitive development in adolescence.

SUMMARY

1. As children acquire more information and knowledge in several domains, their organization of that information becomes important to understand.
2. The Piagetian class-inclusion task is one way to understand how children organize their knowledge about the way different concepts relate to one another.

3. Recent work suggests that in some domains (e.g., biology) children need to develop new theories and understandings as they acquire new information. However, the way theories are acquired and revised may depend in part on the cultural context in which children's lives are embedded.

4. Higher-order cognitive tasks include reasoning, decision making, problem solving, and thinking, as well as academic skills such as reading, writing, and arithmetic.

5. Formal reasoning abilities show some development during the middle childhood years. With familiar, concrete content, most children can reason in ways that are typical for adults. One explanation is that this ability reflects a growing capacity for generating alternatives that are consistent with premises but that lead to different conclusions than the first one thought of. This may relate to growing capacity of the central executive, which enables reasoning processes to be carried out more quickly and efficiently.

6. The complex task of decision making can be divided into five phases: setting goals, gathering information, structuring the decision, making a final choice, and evaluating the process.

7. Although both older and younger children set goals for themselves, older students have more and a different mix of goals, with those relating to school or work becoming more frequent and those relating to leisure time or hobbies becoming less frequent with age. Studies of children's planning abilities suggest that they improve during middle childhood. Older children are reported to participate more in planning their own out-of-school activities than are younger children.

8. With increasing age, children gather information to make a decision in ways very similar to those used by adults. What seems to improve most is children's tendency to approach decisions systematically and efficiently.

9. Children in non-Western cultures who do not attend formal schooling tend to become apprentices to skilled adults during middle childhood. Through a process of guided participation, they learn how to participate in work activities and acquire more knowledge about particular tasks.

10. Learning to read is the dominant classroom activity for children in American schools from kindergarten to Grade 3. Jeanne Chall created a theory of reading development, which includes the following stages: Prereading (ages 0–6), Initial Reading, or Decoding (ages 6–7), Confirmation, Fluency, Ungluing From Print (ages 7–8), and Reading for Learning the New (ages 9–13); other stages in her theory pertain more to high school and college-level reading.

11. Controversy has existed among elementary educators over whether a phonics or a whole-language approach to reading instruction works most effectively. While both approaches have their strengths, empirical evidence underscores the importance of phonemic awareness in teaching children to read.

12. The development of children's writing abilities encompasses concrete aspects, such as handwriting and spelling, and the ability to generate and organize ideas.
13. The development of writing in the early grades (up to about Grade 3) shows that children bring to school a large amount of knowledge about writing (as they also do about reading). Their early attempts at writing and spelling, while unconventional, reflect attempts of the child to communicate through written means.
14. In the upper-elementary grades, children's writing development focuses more on composition, including planning ideas, generating text, and revising.
15. Children in elementary school also learn a lot about arithmetic. They begin by learning facts about addition, subtraction, multiplication, and division and progress to learning more complex procedures such as long division. Children acquire new strategies to use in performing these procedures as they progress through school.
16. Controversy exists among elementary educators over how much emphasis to place on drill and practice of basic facts versus instruction in underlying mathematical principles.
17. Cross-cultural differences in mathematics achievement among elementary school children indicate that arithmetic calculations can be influenced by language as well as the amount of instructional time devoted specifically to mathematics.
18. The popularity of apps for smartphones and tablet computers raises new possibilities for educational interventions and supplements. Past research in the science of learning can guide the development of applications that are best suited to promote learning in children.

REVIEW QUESTIONS

1. Describe the Piagetian class-inclusion task, and discuss the typical findings and what these do and do not imply.
2. Describe and critique the Waxman et al. (2007) study of children's knowledge of biological concepts.
3. Discuss typical research findings on performance with all four conditional reasoning argument types shown in Table 10.2 among elementary-aged children.
4. Describe the phases of decision making. Which show(s) the most developmental differences and why? Justify your answer.
5. What do we know about the development of planning abilities in middle childhood? What important questions remain to be investigated? Make a case for your answer.
6. How well do the findings of Gauvain and Rogoff (1989) and Davidson (1991) fit together to describe developments in higher-order thinking in middle childhood?

7. Explain the concept of guided participation and how it might apply to a child not enrolled in formal schooling.
8. Describe in detail the first four stages of Chall's theory of reading development.
9. Contrast the phonics and whole-language approaches to reading development. Assess what the existing empirical evidence supports.
10. Outline the various stages of the development of writing in the first few years of school. What underlying competencies does each stage reveal?
11. Why might learning to write stories (and other text) relate so heavily to both reading skill and development of the central executive?
12. Critique the drill-and-practice approach to teaching elementary school children basic arithmetic facts.
13. Describe and critique the cross-cultural studies by Geary and colleagues on children's arithmetical knowledge during the elementary school years in China and the United States.

KEY TERMS

Biases

Class-Inclusion Task

Collection

Conditional Reasoning

Drill and Practice

Guided Participation

Heuristics

Naïve Theory Approach (to conceptual development)

Phonemic Awareness

Phonics

Planning

Whole Language