CHAPTER 8
Cognition and Language

- How do our experiences influence our behaviors and mental processes?

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AP LEARNING TARGETS FOR CHAPTER 8

MODULE 23

- Identify problem-solving strategies as well as factors that influence their effectiveness.

THINKING AND REASONING

Mental Images: Examining the Mind's Eye

Concepts: Categorizing the World

Reasoning: Making Up Your Mind

Computers and Problem Solving: Searching for Artificial Intelligence

Does Playing Video Games Improve Your Thinking?

AP Applying Psychology in the 21st Century: Are Our Attention Spans Becoming Shorter?

MODULE 24

- Identify the contributions of key researchers in cognitive psychology.
- List the characteristics of creative thought and creative thinkers.
- Identify problem-solving strategies as well as factors that create bias and errors in thinking.

PROBLEM SOLVING

Preparation: Understanding and Diagnosing Problems

Production: Generating Solutions

Judgment: Evaluating Solutions

Impediments to Solutions: Why Is Problem Solving Such a Problem?

Creativity and Problem Solving

Becoming an Informed Consumer of Psychology: Thinking Critically and Creatively

- Identify the contributions of key researchers in cognitive psychology.

- Synthesize how biological, cognitive, and cultural factors converge to facilitate acquisition, development, and use of language.

PROLOGUE *MIND GAMES*

Shawn Green, a research assistant in a psychology lab at the University of Rochester, was designing a computerized test to study neuroplasticity—the brain's ability to rewire itself in response to new experiences. The test would measure the ability to find particular shapes in a busy visual scene. To try out the test, he took it himself. He discovered what he felt must be an error in the test: he consistently achieved perfect scores, a result not at all in keeping with the results from similar tests at other labs.

Green decided to administer the test to other people. He recruited some of his friends, and astonishingly, they too achieved perfect scores. He tried the test one more time, this time on his supervisor. In contrast to Green and his friends, her performance wasn't exceptional; she had an average score.

What was going on? Eventually, Green and his supervisor realized that he and his friends shared one key trait that enabled them to overachieve on the neuroplasticity test: they were all avid video-game players, spending hours each week online subduing zombies and other villains (Bavelier & Green, 2016).

LOOKING *Ahead*

It turns out that video games, often criticized for producing such negative traits as aggression and mindless addiction, can, under the right circumstances, positively affect some kinds of cognitive abilities. Certain types of games can improve reaction times, decision making under pressure, fine-motor control, task switching, spatial sense, and, especially, attention focusing and distribution.

Results such these have led researchers to consider developing games for therapeutic uses to address targeted types of cognitive deficits induced by aging or trauma (Granic, Lobel, & Engels, 2014; Gabbiandini & Greitemeyer, 2017).

Adapting to new experiences and honing new or existing cognitive skills are just two of the many tasks that our own amazing human computer—the brain—can accomplish in the course of our daily lives, even though we may have little or no idea how it does so. The mystery of how the brain processes language and all its nuances—as well as how it uses information to solve problems and make decisions—is the subject to which we now turn.

Cognitive psychology is the branch of psychology that focuses on the study of higher mental processes, including thinking, language, memory, problem solving, knowing, reasoning, judging, and decision making. Although the realm of cognitive psychology is broad, we will focus on three major topics. The first topic we consider in this chapter is thinking and reasoning. Then we examine different strategies for approaching problems, means of generating solutions, and ways of making judgments about the usefulness and accuracy of solutions. Finally, we discuss how language is developed and acquired, its basic characteristics, and the relationship between language and thought.

cognitive psychology The branch of psychology that focuses on the study of higher mental processes, including thinking, language, memory, problem solving, knowing, reasoning, judging, and decision making. (Module 23)

Module 23
Thinking and Reasoning

What are you thinking about at this moment?

The mere ability to pose such a question underscores the distinctive nature of the human ability to think. No other species contemplates, analyzes, recollects, or plans the way humans do. Understanding what thinking is, however, goes beyond knowing that we think. Philosophers, for example, have argued for generations about the meaning of thinking, with some placing it at the core of human beings' understanding of their own existence.

Psychologists define **thinking** as brain activity in which we mentally manipulate information, including words, visual images, sounds, or other data. Thinking transforms information into new and different forms, allowing us to answer questions, make decisions, solve problems, or make plans.

Although a clear sense of what specifically occurs when we think remains elusive, our understanding of the nature of the fundamental elements involved in thinking is growing. We begin by considering our use of mental images and concepts, the building blocks of thought.

Mental Images: Examining the Mind's Eye

Think of your best friend.

Chances are that you "see" some kind of visual image when asked to think of her or him, or any other person or object, for that matter. To some cognitive psychologists, such mental images constitute a major part of thinking.

Mental images are representations in the mind of an object or event. They are not just visual representations; our ability to "hear" a tune in our heads also relies on a mental image. In fact, every sensory modality may produce corresponding mental images (De Bini, Pazzaglia, & Gardini, 2007; Gardini et al., 2009; Koçak et al., 2011).

Research has found that our mental images have many of the properties of the actual stimuli they represent. For example, it takes the mind longer to scan mental images of large objects than small ones, just as the eye takes longer to scan an actual large object than to scan an actual small one. Similarly, we are able to manipulate and rotate mental images of objects, just as we are able to manipulate and rotate them in the real world (Mast & Kosslyn, 2002; Zacks, 2008; Reisberg, 2013; see Figure 1).

Some experts see the production of mental images as a way to improve various skills. For instance, many athletes use mental imagery in their training. Basketball players may try to produce vivid and detailed images of the court, the basket, the ball, and the noisy crowd. They may visualize themselves taking a foul shot, watching the ball, and hearing the swish as it goes through the net. And it works: The use of mental imagery can lead to improved performance in sports (Moran, 2009; Velentzas, Heinen, & Schack, 2011; Wimmer et al., 2017).

Mental imagery may improve other types of skills as well. For example, piano players who simply mentally rehearse an exercise show brain activity that is virtually identical to that of the people who actually practice the exercise manually. Apparently, carrying out the task involved the same network of brain cells as the network used in mentally rehearsing it (Sanders et al., 2008; Davidson-Kelly et al., 2015).

thinking Brain activity in which people mentally manipulate information, including words, visual images, sounds, or other data. (Module 23)

mental images Representations in the mind of an object or event. (Module 23)
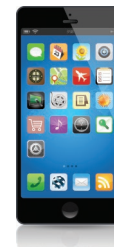
PsychTech

Researcher Adam Wilson has developed a method of tweeting by thinking. The process involves being outfitted with electrodes that react to changes in brain activity. It's slow going, though: the fastest tweeters by thinking are able to create tweets at only 8 characters per minute.

FIGURE 1 Try to mentally rotate one of each pair of patterns to see if it is the same as the other member of that pair. It's likely that the farther you have to mentally rotate a pattern, the longer it will take to decide if the patterns match one another. Does this mean that it will take you longer to visualize a map of the world than a map of the United States? Why or why not?

Source: Adapted from Shepard, R. N., & Metzler, J. (1971). Mental rotation of three-dimensional objects. *Science, 171*(3972), 701–703.

(a)

(b)

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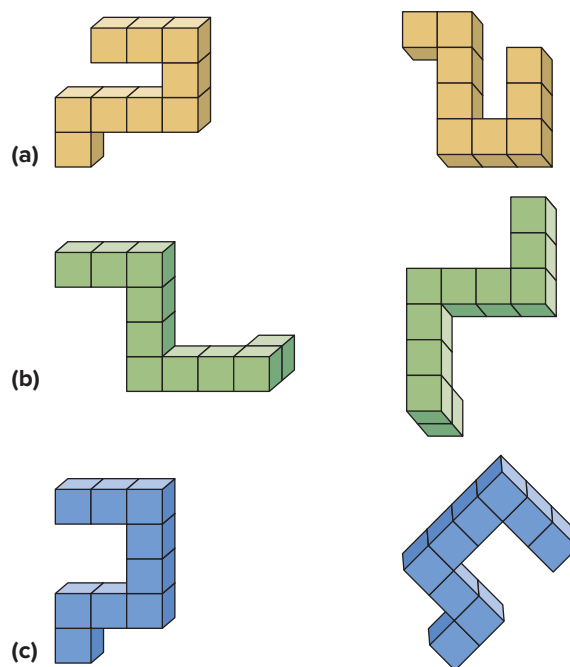
From the perspective of...

A Human Resources Specialist How might you use the research on mental imagery to improve employees' performance?

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Many athletes use mental imagery to focus on a task, a process they call "getting in the zone." What are some other occupations that require the use of strong mental imagery?

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Concepts: Categorizing the World

If someone asks you what is in your kitchen cabinet, you might answer with a detailed list of items (a jar of peanut butter, three boxes of macaroni and cheese, six unmatched dinner plates, and so forth). More likely, though, you would respond by naming some broader categories, such as "food" and "dishes."

Using such categories reflects the operation of concepts. **Concepts** are mental groupings of similar objects, events, or people. Concepts enable us to organize complex phenomena into cognitive categories that are easier to understand and remember (Connolly, 2007; Kreppner et al., 2011; Mack, Love, & Preston, 2016).

Concepts help us classify newly encountered objects on the basis of our past experience. For example, we can surmise that someone tapping a handheld screen is probably using some kind of computer or tablet, even if we have never encountered that specific model before. Ultimately, concepts influence behavior. We would assume, for instance, that it might be appropriate to pet an animal after determining that it is a dog, whereas we would behave differently after classifying the animal as a wolf.

When cognitive psychologists first studied concepts, they focused on those that were clearly defined by a unique set of properties or features. For example, an equilateral triangle is a closed shape that has three sides of equal length. If an object has these characteristics, it is an equilateral triangle; if it does not, it is not an equilateral triangle.

Other concepts–often those with the most relevance to our everyday lives–are more ambiguous and difficult to define. For instance, broader concepts such as "table" and "bird" have a set of general, relatively loose characteristic features, rather than unique, clearly defined properties that distinguish an example of the concept from a nonexample.

When we consider these more ambiguous concepts, we usually think in terms of examples called prototypes. **Prototypes** are typical, highly representative examples of a concept that correspond to our mental image or best example of the concept. For instance, for most people, the prototype of a dog is something like the common beagle, rather than the relatively rare shih tzu, Finnish spitz, otterhound, or mudi (breeds you've probably never heard of). Similarly, although a robin and an ostrich are both examples of birds, the robin is an example that comes to most people's minds far more readily. Consequently, robin is a prototype of the concept "bird."

Relatively high agreement exists among people in particular cultures about which examples of a concept are prototypes as well as which examples are not. For instance, most people in Western cultures consider cars and trucks good examples of vehicles, whereas elevators and wheelbarrows are not considered very good examples. Consequently, cars and trucks are prototypes of the concept of a vehicle (see Figure 2).

Concepts enable us to think about and understand more readily the complex world in which we live. For example, the suppositions we make about the reasons for other

concepts Mental groupings of similar objects, events, or people. (Module 23)

prototypes Typical, highly representative examples of a concept. (Module 23)

Study Alert
Figure 2 will help you remember that prototypes represent "best" or most common examples of a particular concept. For example, a Prius might be a prototype of the concept of "hybrid car."
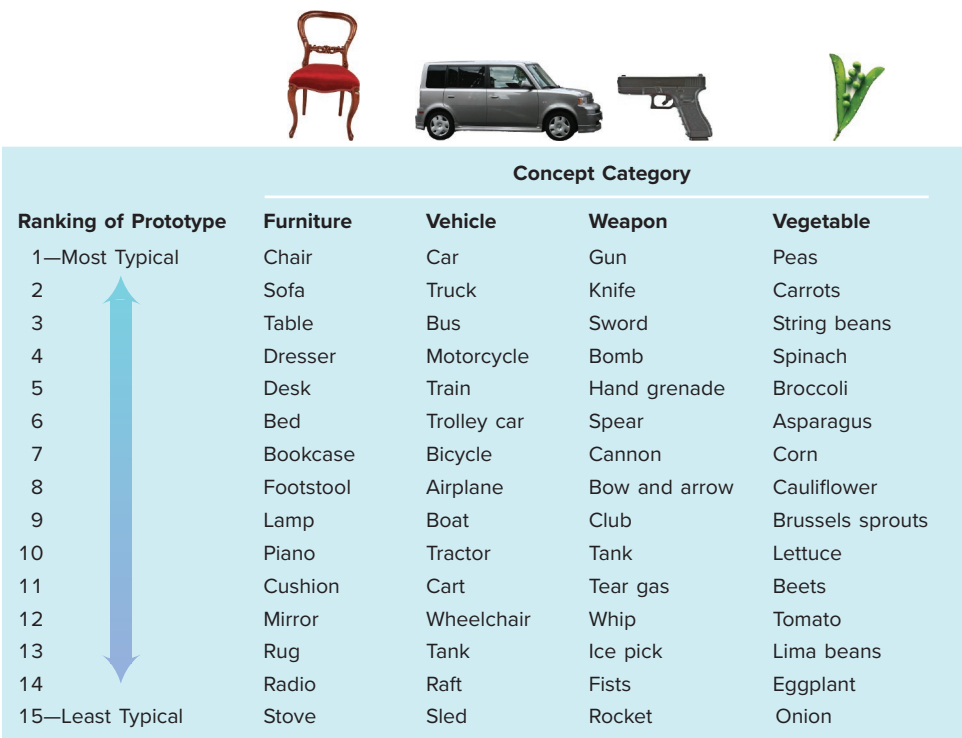

How do you view these dogs? Whether you categorize them as guard dogs (left and middle), as service dogs (middle and right), or simply as three dogs, you are using concepts.
(all): ©Purestock/SuperStock

	Concept Category			
Ranking of Prototype	**Furniture**	**Vehicle**	**Weapon**	**Vegetable**
1—Most Typical	Chair	Car	Gun	Peas
2	Sofa	Truck	Knife	Carrots
3	Table	Bus	Sword	String beans
4	Dresser	Motorcycle	Bomb	Spinach
5	Desk	Train	Hand grenade	Broccoli
6	Bed	Trolley car	Spear	Asparagus
7	Bookcase	Bicycle	Cannon	Corn
8	Footstool	Airplane	Bow and arrow	Cauliflower
9	Lamp	Boat	Club	Brussels sprouts
10	Piano	Tractor	Tank	Lettuce
11	Cushion	Cart	Tear gas	Beets
12	Mirror	Wheelchair	Whip	Tomato
13	Rug	Tank	Ice pick	Lima beans
14	Radio	Raft	Fists	Eggplant
15—Least Typical	Stove	Sled	Rocket	Onion

people's behavior are based on the ways in which we classify behavior. Hence, our conclusion about a person who washes her hands 20 times a day could vary, depending on whether we place her behavior within the conceptual framework of a health-care worker or a mental patient. Similarly, physicians make diagnoses by drawing on concepts and prototypes of symptoms that they learned about in medical school. Finally, concepts and prototypes facilitate our efforts to draw suitable conclusions through the cognitive process we turn to next: reasoning.

Reasoning: Making Up Your Mind

Professors deciding when students' assignments are due.

An employer determining who to hire out of a pool of job applicants.

The president concluding that it is necessary to send troops to a foreign nation.

What do these three situations have in common? Each requires *reasoning*, the process by which information is used to draw conclusions and make decisions.

Although philosophers and logicians have considered the foundations of reasoning for centuries, it is only relatively recently that cognitive psychologists have begun to investigate how people reason and make decisions. Their efforts have contributed to our understanding of formal reasoning processes as well as the cognitive shortcuts we routinely use–shortcuts that sometimes may lead our reasoning capabilities astray (Johnson-Laird, 2006).

FORMAL REASONING

When (the fictitious) Sherlock Holmes sought to solve a crime, he carefully observed the scene of the crime and then made informed guesses about what those observations meant. For example, in one story, the ever-observant Holmes noted that cuts on the side of a shoe suggested that a potential criminal must have had mud on his shoes that needed to be scraped off.

The type of reasoning that Holmes used is known as deductive reasoning. **Deductive reasoning** is reasoning from the general to the specific. Psychologists, like all scientists, use deductive reasoning when they start with a general, broad theory, then derive a hypothesis from the theory, and ultimately test the hypothesis by collecting data to arrive at a conclusion.

The other major class of reasoning is inductive reasoning. **Inductive reasoning** is reasoning from the specific to the general. Inductive reasoning is data driven, in that we accumulate pieces of information and put them together to form a conclusion. That's what psychologists do when they study a sample of participants (for instance, 20 color-blind college students), and then they use the information they observe to form a conclusion about the broader population from which the sample is drawn (all color-blind college students).

If we consistently used deductive and inductive reasoning, we would make decisions and solve problems quite logically. However, as we'll see next, that often doesn't happen, leading to less-than-optimal results.

deductive reasoning Reasoning from the general to the specific. (Module 23)

inductive reasoning Reasoning from the specific to the general. (Module 23)

ALGORITHMS AND HEURISTICS

When faced with making a decision, we often turn to various kinds of cognitive shortcuts, known as algorithms and heuristics, to help us. An **algorithm** is a rule that, if applied appropriately, guarantees a solution to a problem. We can use an algorithm even if we cannot understand why it works. For example, you may know that you can find the length of the third side of a right triangle by using the formula $a^2 + b^2 = c^2$, although you may not have the foggiest notion of the mathematical principles behind the formula.

For many problems and decisions, however, no algorithm is available. In those instances, we may be able to use heuristics to help us. A **heuristic** is a thinking strategy that may lead us to a solution to a problem or decision but–unlike algorithms– may sometimes lead to errors. Heuristics increase the likelihood of success in coming to a solution, but, unlike algorithms, they cannot ensure it. For example, when I play tic-tac-toe, I follow the heuristic of placing an X in the center square when I start the game. This tactic doesn't guarantee that I will win, but experience has taught me that it will increase my chances of success. Similarly, some students follow the heuristic of preparing for a test by ignoring the assigned textbook reading and only studying their lecture notes–a strategy that may or may not pay off.

Although heuristics often help people solve problems and make decisions, certain kinds of heuristics may lead to inaccurate conclusions. For example, the *availability heuristic* involves judging the likelihood of an event occurring on the basis of how easy it is to think of examples. According to this heuristic, we assume that events we remember easily are likely to have occurred more frequently in the past–and are more likely to occur in the future–than events that are harder to remember.

For instance, the availability heuristic makes us more afraid of dying in a plane crash than in an auto accident, despite statistics clearly showing that airplane travel is much safer than auto travel. Similarly, although 10 times as many people die from falling out of bed than from lightning strikes, we're more afraid of being hit by lightning. The reason is that plane crashes and lightning strikes receive far more publicity, and they are therefore more easily remembered (Kluger, 2006; Caruso, 2008; Geurten et al., 2015).

We also make use of a familiarity heuristic. The *familiarity heuristic* leads us to prefer familiar objects, people, and things to those that that are unfamiliar or strange to us. For example, we might purchase a book written by a familiar author rather than one written by an author we never heard of, even if the topic of the book by the unfamiliar author sounds more appealing.

The familiarity heuristic typically saves us a great deal of time when we are making decisions, since we often just go with what seems most familiar. On the other hand, it's not so good if you are an emergency room physician susceptible to the familiarity heuristic. If you simply settle on the first, most obvious diagnosis for a

algorithm A rule that, if applied appropriately, guarantees a solution to a problem. (Module 23)

heuristic A thinking strategy that may lead us to a solution to a problem or decision but–unlike algorithms–may sometimes lead to errors. (Module 23)

Study Alert

Remember that algorithms are rules that *always* provide a solution, whereas heuristics are shortcuts that *may* provide a solution.

patient presenting particular symptoms (the ones that are most familiar to you), you may miss making a more accurate diagnosis (Herbert, 2011).

Are algorithms and heuristics confined to human thinking, or can we program computers to mimic human thinking and problem solving? As we discuss next, scientists are certainly trying.

Computers and Problem Solving: Searching for Artificial Intelligence

To the music experts, there was no mistaking who had written the piano piece: Johann Sebastian Bach, the prolific German composer who was born in the 17th century.

But the experts were wrong. The piece they all thought was a Bach composition was actually created by a computer named "EMI" by David Cope of the University of California. After a variety of Bach pieces had been scanned into its memory, EMI was able to produce music that was so similar to Bach's actual music that it fooled knowledgeable listeners (Johnson, 1997; Cope, 2001).

Such computer mimicry is possible because composers have a particular "signature" that reflects patterns, sequences, and combinations of notes. By employing those "signatures," computers can create compositions that have the full scope and emotional appeal of actual works—and show just as much creativity as those written by the actual composer (Cope, 2001, 2003).

Computers are making significant inroads in terms of the ability to solve problems and carry out some forms of intellectual activities. According to experts who study *artificial intelligence*, the field that examines how to use technology to imitate the outcome of human thinking, problem solving, and creative activities, computers can show rudiments of humanlike thinking because of their knowledge of where to look—and where not to look—for answers to problems. They suggest that the capacity of computer programs such as those that play chess to evaluate potential moves and to ignore unimportant possibilities gives them thinking ability (Megill, 2013; Ghahramani, 2015; Hernández-Orallo, 2017).

Computers using artificial intelligence are particularly good at tasks that require speed, persistence, and a huge memory, as you might realize if you've used Apple's Siri or Amazon's Alexa. For example, artificial intelligence is used today to inform decisions about whether a bank should loan money to a customer, which involve synthesizing vast amounts of information (including loan-repayment history) to determine how likely the customer is to repay the loan. And this is just the start; thousands of job categories, ranging from radiology to truck driving, will likely use artificial intelligence in the future. Still, it remains to be seen whether the quality of thinking produced by artificial intelligence will match that of humans (Luxton, 2016; Gopnik, 2017; Lee, 2017).

A computer using artificial intelligence software was able to mimic compositions by Johann Sebastian Bach so successfully it fooled expert musicologists.
©Photos.com/Getty Images

Does Playing Video Games Improve Your Thinking?

People who love video games spend a great many hours engaged in their pastime. Some rationalize the time spent by claiming that video games sharpen their cognitive skills—that is, they help them become better at solving challenges and problems, or they improve their memory, or they sharpen their attention. And a large number of studies back up those claims, studies showing that gamers perform better than nongamers on a number of tests of cognitive and perceptual abilities, ranging from hand-eye coordination to working memory to control of attention (Powers et al., 2013; Granic, Lobel, & Engels, 2014).

AP APPLYING PSYCHOLOGY IN THE 21ST CENTURY

ARE OUR ATTENTION SPANS BECOMING SHORTER?

Do you have a low tolerance for down time? When you find you have a few minutes to spare, such as while waiting in line at a store checkout or riding in an elevator, do you feel a compulsion to pull out your smartphone and check your e-mail or social media?

If you answered yes, you're not alone; many people report they multitask more than ever. This increase in multitasking has led researchers to ask if the vast and ever-increasing amount of media vying for our attention has had an impact on our attention spans.

To address the issue, software giant Microsoft conducted research involving surveys and brain scans of 2,000 Canadians. The findings showed that attention span, which was defined as the duration of concentrated effort on a task without becoming distracted, had fallen from an average of 12 seconds in 2000 (around the time when mobile devices were taking off) to 8 seconds 15 years later. Attention was worst for participants who were heavier consumers of media, particularly social media, and who were early adopters of new technology or frequently used multiple media devices, such as using a tablet or smartphone while watching television (McSpadden, 2015).

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The researchers suggested that digital media enthusiasts might have simply become very good at quickly determining whether a new task is interesting enough to merit their continued attention. When they become bored, they quickly look elsewhere. However, they also show bursts of high attention, suggesting they are capable of focusing intently when they want to do so.

But this research is not without its critics, who rightly point out that attention span likely varies according to the task we are carrying out. Some tasks are simply more interesting to us than others, and our attention span will likely be lengthier for more engaging activities than for less interesting ones.

Furthermore, attention span reflects the fact that the brain is simply good at adapting to its environment and picking out the stimuli that are the most useful. For example, other research shows that people who play a lot of video games have an enhanced ability to track moving objects, mentally rotate objects, and notice changes—that is, in many ways, their attention to detail is actually better than that of nongamers. Perhaps it's not all that surprising that given the choice between staring at the walls in a waiting room or reading something engaging on a screen in your hand, most people would choose the latter (Basak et al., 2008).

AP SKILL: SCIENTIFIC INVESTIGATION / DEFINE AND/OR APPLY CONCEPTS

1. Describe the correlation between social media and attention span.
2. Do you think there is an advantage to being bored or do you always need to have focused attention?

But this research has its critics, who suggest the benefits of gaming may be overstated. A recent study addressed some of these criticisms, and it found surprising results. Instead of categorizing participants into just two groups, as most studies do (frequent players versus nonplayers), the new study considered the full range of playing frequency, from nonplayers to low-frequency, moderate-frequency, and high-frequency players. When looked at this way, the previous findings that gamers outperformed nongamers on cognitive abilities simply vanished. The researchers concluded that previous studies used methods that had the unintended effect of inflating the apparent influence of video-game play on cognitive measures (Unsworth et al., 2015).

It thus seems that it's still too early to know the actual effects of video game play on cognitive abilities. But the conflicting sets of results suggest caution is necessary when drawing conclusions. (Also see *Applying Psychology in the 21st Century.*)

AP❙ MODULE 23: THINKING AND REASONING

AP SUMMARY

- Cognitive psychology encompasses the higher mental processes, including the way people know and understand the world, process information, make decisions and judgments, and describe their knowledge and understanding to others.
- Mental images are representations in the mind of an object or event. The production of mental images can be used to improve various skills.
- Concepts are categorizations of objects, events, or people that share common properties. Prototypes are representative examples of concepts.
- Deductive reasoning is reasoning from the general to the specific, whereas inductive reasoning is reasoning from the specific to the general.
- Decisions may be improved through the use of algorithms and heuristics. An algorithm is a rule that guarantees a solution; a heuristic is a cognitive shortcut that may lead to a solution but is not guaranteed to do so. Types of heuristics include the availability heuristic and familiarity heuristic.

AP KEY TERMS

cognitive psychology	deductive reasoning
thinking	inductive reasoning
mental images	algorithm
concepts	heuristic
prototypes	

AP TEST PRACTICE

Section I: Multiple Choice

1. In order to find condensed milk at the grocery store, Jessica started in aisle one and systematically went through each aisle until she found the product she was looking for. What problem-solving technique did Jessica use?
   A. Algorithm
   B. Concept
   C. Deductive reasoning
   D. Heuristic
   E. Inductive reasoning

2. What problem-solving technique saves time but is prone to errors?
   A. Echoic
   B. Syllogism
   C. Heuristic
   D. Iconic
   E. Algorithm

3. Savannah took one foreign language class and struggled to succeed. Now she thinks all foreign language classes are too challenging for her. What type of reasoning was used to come to this conclusion?
   A. Inductive
   B. Deductive
   C. Convergent
   D. Divergent
   E. Implicit

Section II: Free Response

Brian needs to buy a new car. Describe how the following terms can help him problem solve when selecting a new car.
- Concept
- Prototype
- Inductive reasoning
- Deductive reasoning
- Availability heuristic

Module 24
Problem Solving

According to an old legend, a group of Vietnamese monks guard three towers on which sit 64 golden rings. The monks believe that if they succeed in moving the rings from the first tower to the third according to a series of rigid rules, the world as we know it will come to an end. (Should you prefer that the world remain in its present state, there's no need for immediate concern: The puzzle is so complex that it will take the monks about a trillion years to solve it.)

In the Tower of Hanoi puzzle, a simpler version of the task facing the monks, three disks are placed on three posts in the order shown in Figure 1. The goal of the puzzle is to move all three disks to the third post, arranged in the same order, by using as few moves as possible. There are two restrictions: Only one disk can be moved at a time, and no disk can ever cover a smaller one during a move.

Why are cognitive psychologists interested in the Tower of Hanoi problem? Because the way people go about solving such puzzles helps illuminate how people solve complex, real-life problems. Psychologists have found that problem solving typically involves the three steps illustrated in Figure 2: preparing to create solutions, producing solutions, and evaluating the solutions that have been generated.

Preparation: Understanding and Diagnosing Problems

When approaching a problem like the Tower of Hanoi, most people begin by trying to understand the problem thoroughly. If the problem is a novel one, they probably will pay particular attention to any restrictions placed on coming up with a solution–such as the rule for moving only one disk at a time in the Tower of Hanoi problem. If, by contrast, the problem is a familiar one, they are apt to spend considerably less time in this preparation stage.

Problems vary from well defined to ill defined. In a *well-defined problem*–such as a mathematical equation or the solution to a jigsaw puzzle–both the nature of the problem itself and the information needed to solve it are available and clear. Thus, we can make straightforward judgments about whether a potential solution is appropriate. With an *ill-defined problem,* such as how to increase morale on an assembly line or to bring peace to the Middle East, not only may the specific nature of the problem be

Study Alert
Use the three steps of problem solving to organize your studying: Preparation, Production, and Judgment (PPJ).
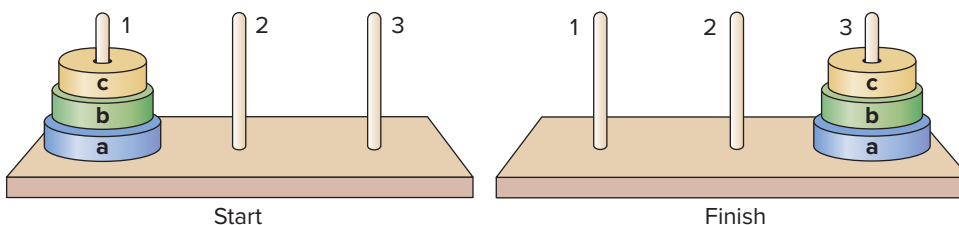

FIGURE 1 The goal of the Tower of Hanoi puzzle is to move all three disks from the first post to the third and still preserve the original order of the disks, using the fewest number of moves possible while following the rules that only one disk at a time can be moved and no disk can cover a smaller one during a move. Try it yourself before you look at the solution, which is given according to the sequence of moves.

Solution: Move C to 3, B to 2, C to 2, A to 3, C to 1, B to 3, and C to 3.

unclear, the information required to solve the problem may be even less obvious (Newman, Willoughby, & Pruce, 2011; Mayer, 2013; Tschentscher & Hauk, 2017).

KINDS OF PROBLEMS

Typically, a problem falls into one of the three categories shown in Figure 3: arrangement, inducing structure, and transformation. Solving each type requires somewhat different kinds of psychological skills and knowledge. (See Figure 4 for solutions to these problems.)

Arrangement problems require the problem solver to rearrange or recombine elements of the problem in a way that will satisfy specific criteria. Usually, several different arrangements can be made, but only one or a few of the arrangements will produce a solution. Anagram problems and jigsaw puzzles are examples of arrangement problems (Coventry et al., 2003; Reed, 2017).

In *problems of inducing structure*, a person must identify the existing relationships among the elements presented in the problem and then construct a new relationship among them. In such a problem, the problem solver must determine not only the relationships among the elements but also the structure and size of the elements involved. In the example shown in Figure 3b, a person must first determine that the solution requires the numbers to be considered in pairs (14-24-34-44-54-64). Only after identifying that part of the problem can a person determine the solution rule (the first number of each pair increases by one, while the second number remains the same).

The Tower of Hanoi puzzle represents the third kind of problem–*transformation problems*–that consist of an initial state, a goal state, and a method for changing the initial state into the goal state. In the Tower of Hanoi problem, the initial state is the original configuration, the goal state is to have the three disks on the third peg, and the method is the rules for moving the disks (Majeres, 2007; Van Belle et al., 2011; Schiff & Vakil, 2015).

Whether the problem is one of arrangement, inducing structure, or transformation, the preparation stage of understanding and diagnosing is critical in problem solving because it allows us to develop our own cognitive representation of the problem and to place it within a personal framework. We may divide the problem into subparts or ignore some information as we try to simplify the task. Winnowing out nonessential information is often a critical step in the preparation stage of problem solving.

REPRESENTING AND ORGANIZING THE PROBLEM

A crucial aspect of the initial encounter with a problem is the way in which we represent, characterize, and organize the information presented to us. Consider the following problem:

> A man climbs a mountain on Saturday, leaving at daybreak and arriving at the top near sundown. He spends the night at the top. The next day, Sunday, he leaves at daybreak and heads down the mountain, following the same path that he climbed the day before. The question is this: Will there be any time during the 2nd day when he will be at exactly the same point on the mountain as he was at exactly that time on the 1st day?

If you try to solve this problem by using algebraic or verbal representations, you will have a good deal of trouble. However, if you represent the problem with the kind of simple diagram shown in Figure 5, the solution will become apparent.

The way in which we represent a problem–and the solution we eventually come to–depends on the way a problem is initially framed for us. Imagine that you were a cancer patient having to choose between either the option of surgery or of radiation, as shown in Figure 6, and you were given some statistical information about the options. What would you choose?

It turns out that participants in a study made very different choices depending on how the problem was framed. When their choices were framed in terms of the likelihood of *survival*, only 18% of participants chose radiation over surgery. However, when the choice was framed in terms of the likelihood of *dying*, 44% chose radiation over surgery–even though the outcomes are similar with either treatment option (Tversky & Kahneman, 1987; Chandran & Menon, 2004).

a. **Arrangement problems**

1. Anagrams: Rearrange the letters in each set to make an English word:

EFCTA   BODUT   IKCTH   IAENV   LIVAN

2. Two strings hang from a ceiling but are too far apart to allow a person to hold one and walk to the other. On the floor are a book of matches, a screwdriver, and a few pieces of cotton. How could the strings be tied together?
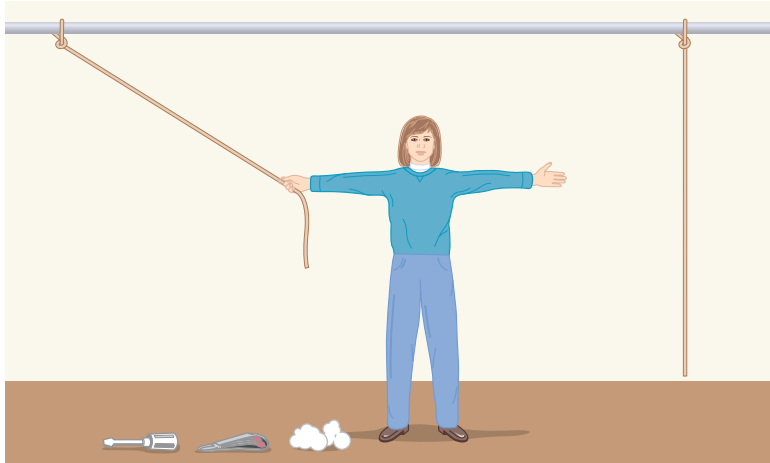
b. **Problems of inducing structure**

1. What number comes next in the series?
    1 4 2 4 3 4 4 4 5 4 6 4
2. Complete these analogies:
    baseball is to bat as tennis is to _____

    merchant is to sell as customer is to _____

c. **Transformation problems**

1. Water jars: A person has three jars with the following capacities:

    Jar A: Jar B: Jar C:
    28 ounces   7 ounces   5 ounces

    How can the person measure exactly 11 ounces of water?

2. Ten coins are arranged in the following way. By moving only *two* of the coins make two rows that each contains six coins.
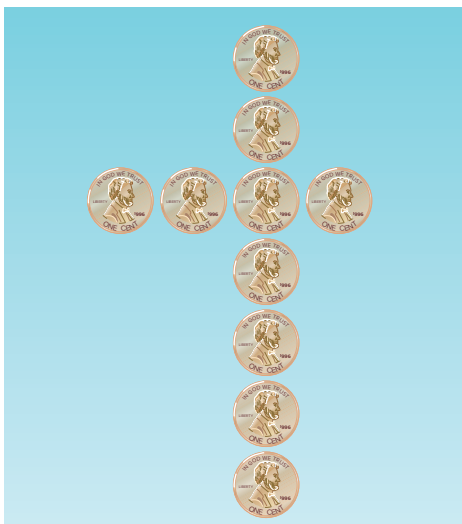
FIGURE 3 The three major categories of problems: (a) arrangement, (b) inducing structure, and (c) transformation. Solutions appear in Figure 4.

Source: Adapted from Bourne, L. E., Dominowski, R. L., Loftus, E. F., & Healy, A. F. (1986). *Cognitive processes* (2nd ed.). Englewood Cliffs, NJ: Prentice Hall.

a. **Arrangement problems**

1. FACET, DOUBT, THICK, NAIVE, ANVIL

2. The screwdriver is tied to one of the strings. This makes a pendulum that can be swung to reach the other string.

b. **Problems of inducing structure**

1. 7

2. racket; buy

c. **Transformation problems**

1. Fill jar A; empty into jar B once and into jar C twice. What remains in jar A is 11 ounces.

2.

Stack one coin in the vertical row in the center, so it becomes part of both rows.

Move one coin in the vertical row to the end of the horizontal row.

FIGURE 4 Solutions to the problems in Figure 3.

Source: Adapted from Bourne, L. E., Dominowski, R. L., Loftus, E. F., & Healy, A. F. (1986). *Cognitive processes* (2nd ed.). Englewood Cliffs, NJ: Prentice Hall.
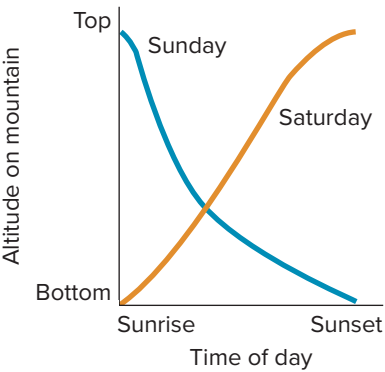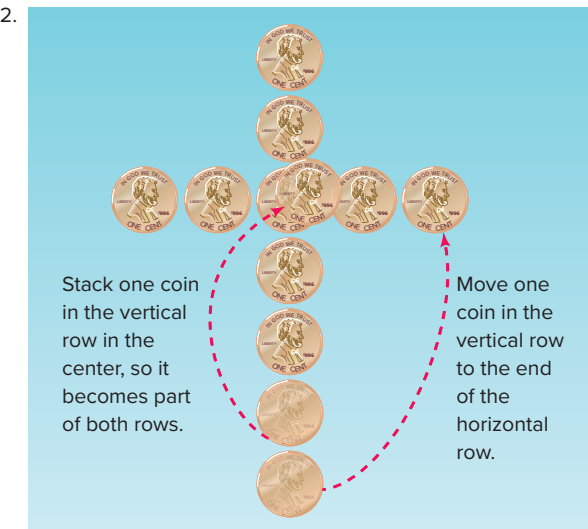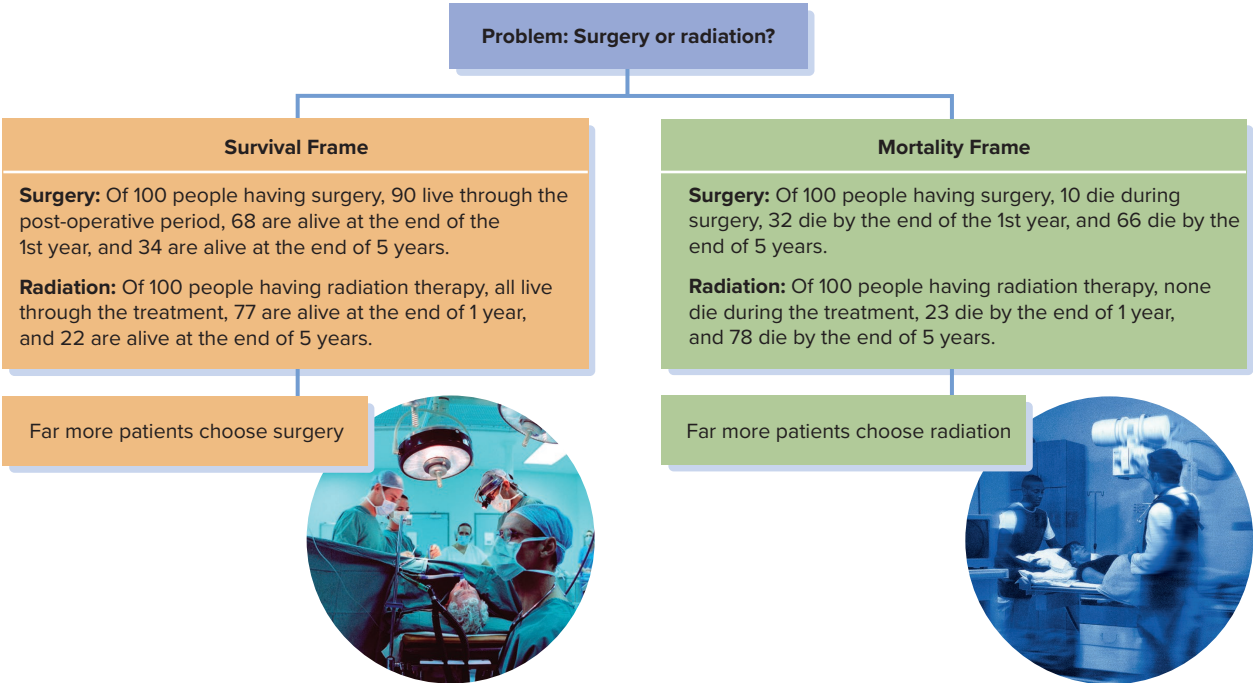

FIGURE 5 You can solve the mountain-climbing problem by using a graph. Keep in mind that the goal is not to determine the time but just to indicate whether an exact time exists. Consequently, the speed at which the traveler is moving is unimportant. Can you think of other approaches that might lead to a solution?

Source: Anderson, B. F. (1980). *The complete thinker: A handbook of techniques for creative and critical problem solving.* Englewood Cliffs, NJ: Prentice Hall.

Problem: Surgery or radiation?

Survival Frame

Surgery: Of 100 people having surgery, 90 live through the post-operative period, 68 are alive at the end of the 1st year, and 34 are alive at the end of 5 years.

Radiation: Of 100 people having radiation therapy, all live through the treatment, 77 are alive at the end of 1 year, and 22 are alive at the end of 5 years.

Far more patients choose surgery

Mortality Frame

Surgery: Of 100 people having surgery, 10 die during surgery, 32 die by the end of the 1st year, and 66 die by the end of 5 years.

Radiation: Of 100 people having radiation therapy, none die during the treatment, 23 die by the end of 1 year, and 78 die by the end of 5 years.

Far more patients choose radiation

FIGURE 6 A decision often is affected by the way a problem is framed. In this case, most would choose radiation over surgery, despite similar results.

(left): ©Hoby Finn/Photodisc/Getty Images; (right): ©Stockbyte/Getty Images

Production: Generating Solutions

After preparation, the next stage in problem solving is the production of possible solutions. If a problem is relatively simple, we may already have a direct solution stored in long-term memory, and all we need to do is retrieve the appropriate information. If we cannot retrieve or do not know the solution, we must generate possible solutions and compare them with information in long- and short-term memory.

At the most basic level, we can solve problems through trial and error. Thomas Edison invented the lightbulb only because he tried thousands of different kinds of materials for a filament before he found one that worked (carbon). The difficulty with trial and error, of course, is that some problems are so complicated that it would take a lifetime to try out every possibility. For example, according to some estimates, there are some 10^{120} possible sequences of chess moves (Fine & Fine, 2003).

In place of trial and error, complex problem solving often involves the use of heuristics, cognitive shortcuts that can generate solutions, as we have discussed. One of the most frequently applied heuristics in problem solving is a means-ends analysis. In a **means-ends analysis,** a problem solver starts by considering the ultimate goal (the end) and determining the best strategy (the means) for attaining the goal. Using a means-end analysis, problem solvers repeatedly test for differences between a desired outcome and the situation that currently exists, trying to get closer and closer to the goal (Bosse, Gerritsen, & Treur, 2011; Bieberstein & Roosen, 2015).

Consider this simple example of a means-ends analysis:

> I want to take my son to preschool. What's the difference between what I have and what I want? One of distance. What changes distance? My automobile. My automobile won't work. What is needed to make it work? A new battery. What has new batteries? An auto repair shop. . . .

In a means-end analysis, each step brings the problem solver closer to a resolution. Although this approach is often effective, if the problem requires indirect steps that temporarily *increase* the discrepancy between a current state and the solution, means-ends analysis can be counterproductive. For example, sometimes the fastest route to the summit of a mountain requires a mountain climber to backtrack temporarily; a means-end approach–which implies that the mountain climber should always forge ahead and upward–will be ineffective in such instances.

For other problems, the best approach is to work backward by focusing on the goal, rather than the starting point, of the problem. Consider, for example, the water lily problem:

> Water lilies are growing on Blue Lake. The water lilies grow rapidly, so that the amount of water surface covered by lilies doubles every 24 hours. On the first day of summer, there was just one water lily. On the 90th day of the summer, the lake was entirely covered. On what day was the lake half covered? (Reisberg, 1997)

If you start searching for a solution to the problem by thinking about the initial state on day 1 (one water lily) and move forward from there, you're facing a daunting task of trial-and-error estimation. But try taking a different approach: Start with day 90, when the entire lake was covered with lilies. Given that the lilies double their coverage daily, on the prior day only half the lake was covered. The answer, then, is day 89, a solution found by working backward (Bourne et al., 1986; Hunt, 1994; Shogren & Wehrmeyer, 2017).

FORMING SUBGOALS: DIVIDING PROBLEMS INTO THEIR PARTS

Another heuristic commonly used to generate solutions is to divide a problem into intermediate steps, or *subgoals,* and solve each of those steps. For instance, in our modified Tower of Hanoi problem, we could choose several obvious subgoals, such as moving the largest disk to the third post.

means-ends analysis A strategy in which a problem-solver considers the ultimate goal (the end) and determines the best strategy for attaining the goal. (Module 24)

If solving a subgoal is a step toward the ultimate solution to a problem, identifying subgoals is an appropriate strategy. In some cases, however, forming subgoals is not all that helpful and may actually increase the time needed to find a solution. For example, some problems cannot be subdivided. Others–like some complicated mathematical problems–are so complex that it takes longer to identify the appropriate subdivisions than to solve the problem by other means (Kaller et al., 2004; Fishbach, Dhar, & Zhang, 2006).

INSIGHT: SUDDEN AWARENESS

Have you ever had this experience? You're working on a difficult problem, mulling over possible answers, but you can't seem to come up with a viable solution. And then, seemingly out of nowhere, a solution comes to you.

If this has happened to you, you experienced a process known as insight. **Insight** is a sudden awareness of the relationships among various elements that had previously appeared to be unrelated. The phenomenon of insight was demonstrated in a classic study by German psychologist Wolfgang Köhler, who examined learning and problem-solving processes in chimpanzees (Köhler, 1927). In his studies, Köhler exposed chimps to challenging situations in which the elements of the solution were all present; all the chimps needed to do was put them together.

In one of Köhler's studies, chimps were kept in a cage in which boxes and sticks were strewn about, and a bunch of tantalizing bananas was hung from the ceiling, out of reach. Initially, the chimps made trial-and-error attempts to get to the bananas: They would throw the sticks at the bananas, jump from one of the boxes, or leap wildly from the ground. Frequently, they would seem to give up in frustration, leaving the bananas dangling temptingly overhead. But then, in what seemed like a sudden revelation, they would stop whatever they were doing and stand on a box to reach the bananas with a stick (Figure 7). Köhler used the term *insight* to label the cognitive process underlying the chimps' new behavior.

Although Köhler emphasized the apparent suddenness of insightful solutions, subsequent research has shown that prior experience and trial-and-error practice in problem solving must precede "insight." Consequently, the chimps' behavior may simply

insight A sudden awareness of the relationships among various elements that had previously appeared to be independent of one another. (Module 24)
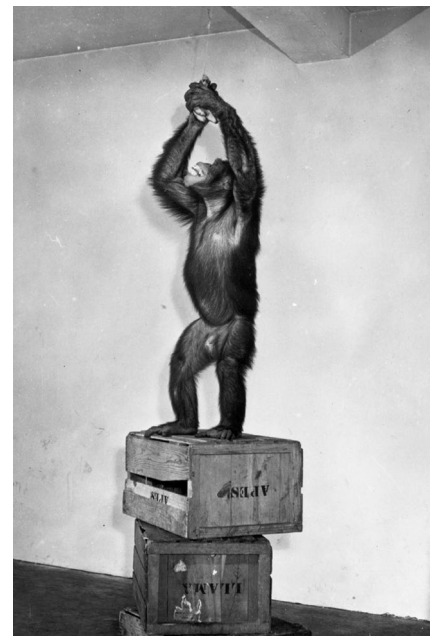
PsychTech

Research comparing people working together to solve problems face-to-face versus communicating via e-mail finds that those using e-mail are more satisfied with the process and believe they find better solutions.

(a)   (b)   (c)

FIGURE 7 (a) In an impressive display of insight, Sultan, one of the chimpanzees in Köhler's experiments in problem solving, sees a bunch of bananas that is out of reach. (b) He then carries over several crates, stacks them, and (c) stands on them to reach the bananas.

(all): ©Superstock

represent the chaining together of previously learned responses, no different from the way a pigeon learns, by trial and error, to peck a key (Kizilirmak et al., 2015).

Can we help people achieve insight when they are seeking to solve problems? The answer is yes. One way is to directly train them, giving them practice in generating solutions that require out-of-the-box thinking. Another way is to provide cross-cultural experiences that show people that their traditional ways of thinking may be inadequate when applied to the problems faced by those living in other cultures (Leung & Chiu, 2010; Wen, Butler, & Koutstaal, 2013).

Judgment: Evaluating Solutions

The final stage in problem solving is judging the adequacy of a solution. Often this is a simple matter: If the solution is clear–as in the Tower of Hanoi problem–we will know immediately whether we have been successful (Varma, 2007).

If the solution is less concrete or if there is no single correct solution, evaluating solutions becomes more difficult. In such instances, we must decide which alternative solution is best. Unfortunately, we often quite inaccurately estimate the quality of our own ideas. For instance, a team of drug researchers working for a particular company may consider their remedy for an illness to be superior to all others, overestimating the likelihood of their success and downplaying the approaches of competing drug companies (Eizenberg & Zaslavsky, 2004; Mihalca, Mengelkamp, & Schnotz, 2017).

Theoretically, if we rely on appropriate heuristics and valid information, we can make accurate choices among alternative solutions. However, several kinds of obstacles to problem solving act to bias the decisions and judgments we make. In fact, a wide range of behaviors are affected by these biases, ranging from the judgments we form of others to the choices we make about financial investments. Examining biases in decision making has influenced the development of an influential new field known as *behavioral economics*, which examines how psychological factors can explain economic decision making (Cox, Green, & Hennig-Schmidt, 2016; Peters et al., 2017).

Impediments to Solutions: Why Is Problem Solving Such a Problem?

Consider the following problem-solving test illustrated in Figure 8 (Duncker, 1945):

> You are given a set of tacks, candles, and matches, each in a small box, and told your goal is to place three candles at eye level on a nearby door so that wax will not drip on the floor as the candles burn. How would you approach this challenge?

If you have difficulty solving the problem, you are not alone. Most people cannot solve it when it is presented in the manner illustrated in the figure, in which the objects are *inside* the boxes. However, if the objects were presented *beside* the boxes, just resting on the table, chances are that you would solve the problem much more readily–which, in case you are wondering, requires tacking the boxes to the door and then placing the candles inside them (see Figure 9).
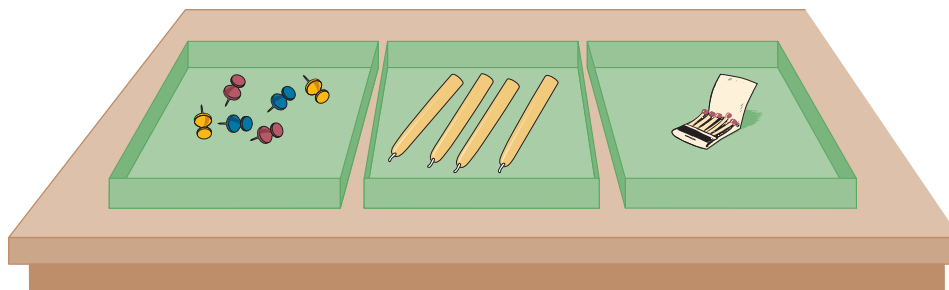

FIGURE 8 The problem here is to place three candles at eye level on a nearby door so that the wax will not drip on the floor as the candles burn—using only material in the figure. For a solution, see Figure 9.

Source: Adapted from Duncker, K. (1945). On problem solving. *Psychological Monographs, 58* (5, whole no. 270).
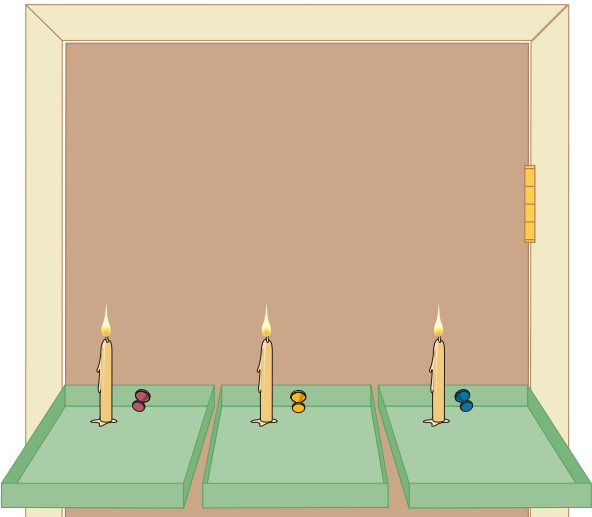
FIGURE 9 A solution to the problem in Figure 8 involves tacking the boxes to the door and placing the candles in the boxes.

Source: Adapted from Duncker, K. (1945). On problem solving. *Psychological Monographs, 58* (5, whole no. 270).

functional fixedness The tendency to think of an object only in terms of the way it is most frequently or typically used. (Module 24)

The difficulty you probably encountered in solving this problem stems from its presentation, which misled you at the initial preparation stage. Actually, significant obstacles to problem solving can exist at each of the three major stages. Although cognitive approaches to problem solving suggest that thinking proceeds along fairly rational, logical lines as a person confronts a problem and considers various solutions, several factors can hinder the development of creative, appropriate, and accurate solutions.

FUNCTIONAL FIXEDNESS

The impediment to solving the candle problem is functional fixedness. **Functional fixedness** is the tendency to think of an object only in terms of the way it is most frequently or typically used. For instance, functional fixedness probably leads you to think of a book as something to read instead of its potential use as a doorstop or as kindling for a fire. In the candle problem, because the objects are first presented inside the boxes, functional fixedness leads most people to see the boxes simply as containers for the objects they hold rather than as a potential part of the solution. They cannot envision another function for the boxes.

A classic experiment (Luchins, 1946) demonstrates functional fixedness. As you can see in Figure 10, the object of the task is to use the jars in each row to measure out the designated amount of liquid. (Try it yourself to get a sense of the power of functional fixedness before moving on.)

If you have tried to solve the problem, you know that the first five rows are all solved in the same way: First fill the largest jar (B) and then from it fill the middle-size jar (A) once and the smallest jar (C) two times. What is left in B is the designated amount. (Stated as a formula, the designated amount is B–A–2C.) The demonstration of functional fixedness comes in the sixth row of the problem, a point at which you probably encountered some difficulty. If you are like most people, you tried the formula and were perplexed when it failed. Chances are, in fact, that you missed the simple (but different) solution to the problem, which involves merely subtracting C from A. Interestingly, people who were given the problem in row 6 *first* had no difficulty with it at all.

Functional fixedness can affect perceptions as well as patterns of problem solving. It can prevent you from seeing beyond the apparent constraints of a problem. For example, try to draw four straight lines so that they pass through all nine dots in the grid below–without lifting your pencil from the page.

FIGURE 10 Try this classic demonstration, which illustrates the importance of functional fixedness in problem solving. The object is to use the jars in each row to obtain the designated amount of liquid.

Given jars with these capacities (in ounces):

	A	B	C	Obtain:
1.	21	127	3	100
2.	14	163	25	99
3.	18	43	10	5
4.	9	42	6	21
5.	20	59	4	31
6.	28	76	3	25

If you had difficulty with the problem, it was probably because you felt compelled to keep your lines within the grid. If you had gone outside the boundaries, however, you would have succeeded by using the solution shown in Figure 11. (The phrase "thinking outside the box"–a commonly used term to encourage creativity–stems from research on overcoming the constraining effects of functional fixedness.)

INACCURATE EVALUATION OF SOLUTIONS

When the United States invaded Iraq in 2003, it did so because governmental leaders believed that the country secretly had weapons of mass destruction that posed a danger to the United States. But later evidence showed that the belief was false. Still, government leaders had made up their minds early on that there were such weapons, and they ignored contradictory evidence and focused more on information that supported their view (U.S. Senate Select Committee on Intelligence, 2004).

The mistake made by governmental leaders exemplifies **confirmation bias** in which problem solvers prefer their first hypothesis and ignore contradictory information that supports alternative hypotheses or solutions. Even when we find evidence that contradicts a solution we have chosen, we are apt to stick with our original hypothesis.

Confirmation bias occurs for several reasons. For one thing, because rethinking a problem that appears to be solved already takes extra cognitive effort, we are apt to stick with our first solution. For another, we give greater weight to subsequent information that supports our initial position than to information that is not supportive of it (Koslowski, 2013; Rajsic, Wilson, & Pratt, 2015; Mercier, 2017).

Creativity and Problem Solving

Despite obstacles to problem solving, many people adeptly discover creative solutions to problems. One enduring question that cognitive psychologists have sought to answer is what factors underlie **creativity,** the ability to generate original ideas or solve problems in novel ways.

Understanding the stages people go through as they approach and solve problems still leaves us with the question: Why are some people better at finding good solutions than other people are? Even the simplest situations reveal a wide range of abilities in problem solving. To explore this for yourself, make a list of all the uses you can think of for a glass jar. When you feel you have run out of possibilities, compare your list to this one compiled by a 12-year-old girl:

> You can keep seashells from your vacation in it to decorate your room. You can put sand on the bottom of it and pour melted wax over the sand and stick a wick in it to make a candle. You can use it as a drinking glass. You can keep rubber bands or paper clips or colored marbles in it. You can make a granola mix and store it for months if the jar has a tight lid. You can put water in the bottom and start an avocado tree from a pit. You can store bacon grease in a jar or fill it with hand soaps and place it by the bathroom sink. You can use it as a flower vase or a "candy dish" for wrapped candies. If you punch holes in the lid, a jar can be a salt or sugar shaker. You can layer pudding and berries and whipped cream in it for a fancy dessert. You can keep your loose change in a jar or use it as a cocktail shaker. You can keep your goldfish in it while you clean the tank. You can organize shelves in the garage or basement by putting small things like nails and screws and bolts with others of the same size, each in their own jar. You can organize your pantry, too: a jar for white rice, one for wild rice, another for black beans, and so on. You can measure rainfall for a month with a jar. Or place it beneath a leaky sink pipe.
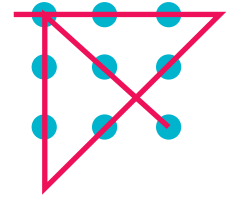

FIGURE 11 A solution to the nine-dot problem requires the use of lines drawn beyond the boundaries of the figure—something that our functional fixedness may prevent us from seeing easily.

confirmation bias The tendency to seek out and weight more heavily information that supports one's initial hypothesis and to ignore contradictory information that supports alternative hypotheses or solutions. (Module 24)

creativity The ability to generate original ideas or solve problems in novel ways. (Module 24)

Singer, songwriter, and activist Lady Gaga is considered a trailblazer in both music and fashion. Do you think she relies more on convergent or divergent thinking in her work?

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divergent thinking Thinking that generates multiple and unusual, although appropriate, responses to problems or questions. (Module 24)

convergent thinking Thinking in which a problem is viewed as having a single answer and which produces a solution that is based primarily on knowledge and logic. (Module 24)

Study Alert
Remember *d*ivergent thinking produces *d*ifferent and *d*iverse kinds of responses, whereas convergent thinking produces more *c*ommonsense kinds of responses.

This list shows extraordinary creativity. Unfortunately, it is much easier to identify *examples* of creativity than to determine its causes. Similarly, it's not clear that the kind of creativity shown by highly creative people in the arts, such as singer Lady Gaga, is the same kind of creativity shown by highly creative people in the sciences, such as Steven Hawking (Simonton, 2009; Lavazza & Manzotti, 2013; Yi, Plucker, & Guo, 2015).

However, we do know that several characteristics are associated with creativity. For one thing, highly creative individuals show divergent thinking. **Divergent thinking** is thinking that generates multiple and unusual, although appropriate, responses to problems or questions. When we use "out-of-the-box" thinking, we're showing divergent thinking.

Divergent thinking contrasts with convergent thinking. **Convergent thinking** is thinking in which a problem is viewed as having a single answer and which produces a solution that is based primarily on knowledge and logic. For instance, someone relying on convergent thinking would answer "You read it" to the query "What can you do with a newspaper?" In contrast, "You can use it as a dustpan" is a more divergent–and creative–response (Schepers & van den Berg, 2007; Zeng, Proctor, & Salvendy, 2011; Haas, 2017).

Creative people also show cognitive complexity in their thinking. *Cognitive complexity* is the preference for elaborate, intricate, and complex thoughts and solutions to problems. For instance, creative people often have a wider range of interests and are more independent and more interested in philosophical or abstract problems than are less creative individuals (Barron, 1990; Richards, 2006; Kaufman & Plucker, 2011).

From the perspective of...

A Manufacturer How might you encourage your employees to develop creative ways to improve the products you produce?

©Kali Nine LLC/Getty Images

One factor that is *not* closely related to creativity is intelligence. Traditional intelligence tests, which ask focused questions that have only one acceptable answer, tap convergent thinking skills. Highly creative people may therefore find that such tests penalize their divergent thinking. This may explain why researchers consistently find that creativity is only slightly related to school grades and intelligence when intelligence is measured using traditional intelligence tests (Heilman, 2005; Norton, Heath, & Ventura, 2013; Jung & Chang, 2017).

Does creativity change as we age? Research suggests that we actually become *less* creative the older we get. One reason may be that as we get older, we know more. Although this increased knowledge is generally advantageous, it may hinder creativity because we are more apt to ignore evidence that contradicts what we believe to be true. In a sense, we get stuck in our ways. Furthermore, when we get older, we already have developed a set of solutions to common problems, and we are more likely to turn to them and avoid exploring more creative ideas. In short, getting older is not helpful in finding creative solutions to problems (Gopnik, Griffiths, & Lucas, 2015; Gopnik & Griffiths, 2017).

BECOMING AN INFORMED CONSUMER
of Psychology

Thinking Critically and Creatively

Can we learn to be better and more creative thinkers?

Cognitive researchers have found that people can learn the abstract rules of logic and reasoning and that such knowledge can improve our reasoning about the underlying causes of everyday events in our lives. Research suggests that critical and creative thinkers are made, not born. Consider, for instance, the following suggestions for increasing critical thinking and creativity (Burbach, Matkin, & Fritz, 2004; Kaufman & Baer, 2006).

- *Redefine problems*. We can modify boundaries and assumptions by rephrasing a problem at either a more abstract or a more concrete level.
- *Use subgoals*. By developing subgoals, we can divide a problem into intermediate steps. This process, known as *fractionation*, allows us to examine each part for new possibilities and approaches, leading to a novel solution for the problem as a whole.
- *Adopt a critical perspective*. Rather than passively accepting assumptions or arguments, we can evaluate material critically, consider its implications, and think about possible exceptions and contradictions.
- *Consider the opposite*. By considering the opposite of a concept we're seeking to understand, we can sometimes make progress. For example, to define "good mental health," it may be useful to consider what "bad mental health" means.
- *Use analogies*. Analogies provide alternative frameworks for the interpretation of facts and help us uncover new understanding. One particularly effective means of coming up with analogies is to look for examples in the animal world. For instance, architects discovered how to construct the earliest skyscrapers by noting how lily pads on a pond could support the weight of a person (Getner & Holyoak, 1997; Bearman, Ball, & Ormerod, 2007; Cho, Holyoak, & Cannon, 2007).

The Disney Concert Hall in Los Angeles, designed by legendary architect Frank Gehry, is known as a masterpiece of visionary architecture. What processes might account for Gehry's creativity?
©tupungato/123RF

- *Think divergently*. Instead of the most logical or common use for an object, consider how you might use the object if you were forbidden to use it in the usual way.
- *Think convergently*. Although it sounds counterintuitive, researchers have found that a combination of divergent *and* convergent thinking can lead to greater creativity. Programs that attempt to teach children to be more creative train participants to alternate periods of divergent thinking with intense convergent thinking (Beghetto & Kaufman, 2010).
- *Use heuristics*. Heuristics are cognitive shortcuts that can help bring about a solution to a problem. If the problem has a single correct answer and you can use or construct a heuristic, you can often find the solution more rapidly and effectively.
- *Experiment with various solutions*. Don't be afraid to use different routes to find solutions for problems (verbal, mathematical, graphic, even dramatic). For instance, try to come up with every conceivable idea you can, no matter how wild or bizarre it may seem at first. After you've come up with a list of solutions, review each one and try to think of ways to make what at first appeared impractical seem more feasible.
- *Walk away*. Sometimes just taking a step back from a problem you're trying to solve and doing something routine and even thoughtless can help bring about creativity. Watching TV, taking a shower, or having a snack may free our minds to come up with innovative solutions (Wiley & Jarosz, 2012; Shellenbarger, 2013).

AP❙ MODULE 24: PROBLEM SOLVING

AP SUMMARY

- Wolfgang Köhler's research with chimpanzees illustrated insight, a sudden awareness of the relationships among elements that had previously seemed unrelated.
- Creativity is the ability to generate original ideas or solve problems in novel and useful ways. Creativity is related to divergent thinking (the ability to generate multiple unusual, but still appropriate, responses to problems) and cognitive complexity. In contrast, convergent thinking is seen as thinking in which a problem is viewed as having a single answer and produces a solution based primarily on knowledge and logic.
- Intelligence is not closely related to creativity and research suggests we become less creative the older we get.
- Suggestions to increase critical thinking and creativity include redefining a problem; adopting a critical perspective and considering the opposite; using an analogy, divergent and convergent thinking, and a heuristic; experimenting with solutions; and sometimes just walking away from the problem.
- Problem solving typically involves three major stages: preparation, production of solutions, and evaluation of solutions that have been generated.
- Preparation involves placing the problem in one of

three categories. In arrangements problems, a group of elements must be rearranged in a way that will satisfy a certain criterion. In problems of inducing structure, a person first must identify the existing relationship among the elements presented and then construct a new relationship among them. Finally, transformation problems consist of an initial state, a goal state, and a method for changing the initial state into the goal state.

- A crucial aspect of the preparation stage is the representation and organization of the problem.
- In the production stage, people try to generate solutions. They may find solutions to some problems in long-term memory. Alternatively, they may solve some problems through simple trial and error and use algorithms and heuristics to solve more complex problems. Common heuristics include a means-end analysis or dividing a problem into subgoals and solving each of those steps.
- Obstacles to problem solving act to bias the decisions and judgments we make. Behavioral economics examines how psychological factors and biases can explain economic decision making.
- Several factors hinder effective problem solving. Functional fixedness is the cognitive bias in which we think of an object only in terms of the way it is most frequently or typically used. Confirmation bias, in which initial hypotheses are favored, can hinder the accurate evaluation of solutions to problems.

AP KEY TERMS

means-ends analysis
insight
functional fixedness
confirmation bias
creativity
divergent thinking
convergent thinking

AP TEST PRACTICE

Section I: Multiple Choice

1. In a famous problem-solving experiment, chimpanzees were provided bananas just out of their reach. Suddenly, a chimp carries over several crates, stacks them, and stands on them to reach the bananas. What problem solving strategy was used in this experiment?
   A. Insight
   B. Deductive reasoning
   C. Convergent thinking
   D. Functional fixedness
   E. Means-ends analysis

2. Why type of thinking is associated with creativity?
   A. Convergent
   B. Deductive
   C. Divergent
   D. Inductive
   E. Explicit

3. Serena can think of over 30 things to do with a paper clip. She has overcome which obstacle to problem solving?
   A. Framing
   B. Hindsight bias
   C. Confirmation bias
   D. Convergent thinking
   E. Functional fixedness

Section II: Free Response

Mrs. Karlin is having problems with her third hour class. There are multiple students that are talking out of turn, so she seats those students at the front of the room. She has found several education articles that support that strategy. In addition, each time they talk out of turn she firmly scolds them. However, these methods do not appear to be working because the students continue to talk and even more students are now misbehaving.

A. Explain how the following concepts could relate to Mrs. Karlin and her problem solving.
   • Confirmation bias
   • Convergent thinking
   • Insight

B. Describe how the following concepts could help explain what is happening in Mrs. Karlin's classroom.
   • Positive reinforcement
   • Observational learning

Module 25
Language

language The communication of information through symbols arranged according to systematic rules. (Module 25)

'Twas brillig, and the slithy toves
Did gyre and gimble in the wabe:
All mimsy were the borogoves,
And the mome raths outgrabe.

Although few of us have ever come face to face with a tove, we have little difficulty in discerning that in Lewis Carroll's (1872) poem "Jabberwocky," the expression *slithy toves* contains an adjective, *slithy*, and the noun it modifies, *toves*.

Our ability to make sense out of nonsense, if the nonsense follows typical rules of language, illustrates the complexity of both human language and the cognitive processes that underlie its development and use. The use of **language**–the communication of information through symbols arranged according to systematic rules–is a central cognitive ability, one that is indispensable for us to communicate with one another. Not only is language central to communication, but it is also closely tied to the very way in which we think about and understand the world. Without language, our ability to transmit information, acquire knowledge, and cooperate with others would be tremendously hindered. No wonder psychologists have devoted considerable attention to studying language (Reisberg, 2009; LaPointe, 2013; Carnevale, Luna, & Lerman, 2017).

Grammar: Language's Language

To understand how language develops and relates to thought, we first need to review some of the formal elements of language. The basic structure of language rests on **grammar,** the system of rules that determine how our thoughts can be expressed.

grammar The system of rules that determine how our thoughts can be expressed. (Module 25)

Grammar deals with three major components of language: phonology, syntax, and semantics. **Phonology** is the study of **phonemes,** the smallest basic units of speech that affect meaning, and of the way we use those sounds to form words and produce meaning. For instance, the *a* sound in *fat* and the *a* sound in *fate* represent two different phonemes in English (Hardison, 2006; Creel & Bregman, 2011).

phonology The study of the smallest units of speech, called phonemes. (Module 25)

phonemes The smallest units of speech. (Module 25)

Linguists have identified 869 different phonemes among all the world's languages. Although English speakers use just 52 phonemes to produce words, other languages use as few as 15 to as many as 141. Differences in phonemes are one reason people have difficulty learning other languages. For example, for a Japanese speaker, whose native language does not have an *r* phoneme, pronouncing such English words as *roar* presents some difficulty (Gibbs, 2002; Iverson et al., 2003; Redford, 2017).

syntax Ways in which words and phrases can be combined to form sentences. (Module 25)

Syntax refers to the rules that indicate how words and phrases can be combined to form sentences. Every language has intricate rules that guide the order in which words may be strung together to communicate meaning. English speakers have no difficulty recognizing that "TV down the turn" is not a meaningful sequence, whereas "Turn down the TV" is. To understand the effect of syntax in English, consider the changes in meaning caused by the different word orders in the following three utterances: "John kidnapped the boy," "John, the kidnapped boy," and "The boy kidnapped John" (Robert, 2006; Frank, Goldwater, & Keller, 2013).

semantics The aspect of language referring to the meaning of words and sentences. (Module 25)

Semantics is the third major component of language. **Semantics** refers to the meaning of words and sentences. Every word has particular semantic features. For example, *boy* and *man* share certain semantic features (both refer to males), but they also differ semantically (in terms of age).

Semantic rules allow us to use words to convey the subtle nuances in meaning. For instance, we can use slightly different wording–semantics–about an event to convey subtle differences in meaning. If we had just seen a girl named Laura get hit by a truck, we might say, "A truck hit Laura." But if we were answering a question about why Laura was not at a party the night before, we might say, "Laura was hit by a truck" (Pietarinen, 2006; Paciorek & Williams, 2015; Srinivasan et al., 2017).

Despite the complexities of language, most of us acquire the basics of grammar without even being aware that we have learned its rules. Moreover, even though we may have difficulty explicitly stating the rules of grammar, our linguistic abilities are so sophisticated that we can utter an infinite number of different statements. How do we acquire such abilities?

Language Development: Developing a Way with Words

To parents, the sounds of their infant babbling and cooing are music to their ears (except, perhaps, at 3 o'clock in the morning). These sounds also serve an important function. They mark the first step on the road to the development of language.

BABBLING

Children **babble**–make speechlike but meaningless sounds–from around the age of 3 months through 1 year. While babbling, they may produce, at one time or another, any of the sounds found in all languages, not just the language to which they are exposed. Even deaf children display their own form of babbling because infants who are unable to hear yet who are exposed to sign language from birth "babble" with their hands (Pettito, 1993; Majorano & D'Odorico, 2011; Shehata-Dieler et al., 2013).

An infant's babbling increasingly reflects the specific language being spoken in the infant's environment, initially in terms of pitch and tone and eventually in terms of specific sounds. Young infants can distinguish among all 869 phonemes that have been identified across the world's languages. However, after the age of 6 to 8 months, that ability begins to decline. Infants begin to "specialize" in the language to which they are exposed as neurons in their brains reorganize to respond to the particular phonemes infants routinely hear.

Some theorists argue that a *critical period* exists for language development early in life in which a child is particularly sensitive to language cues and most easily acquires language. In fact, if children are not exposed to language during this critical period, later they will have great difficulty overcoming this deficit (Bates, 2005; Shafer & Garrido-Nag, 2007; Choubsaz & Gheitury, 2017).

Cases in which abused children have been isolated from contact with others support the theory of such critical periods. In one case, for example, a girl named Genie was exposed to virtually no language from the age of 20 months until she was rescued at age 13. She was unable to speak at all. Despite intensive instruction, she learned only some words and was never able to master the complexities of language (Rymer, 1994; Veltman & Browne, 2001).

PRODUCTION OF LANGUAGE

By the time children are approximately 1 year old, they stop producing sounds that are not in the language to which they have been exposed. It is then a short step to the production of actual words. In English, these are typically short words that start with a consonant sound such as b, d, m, p, and t–this helps explain why *mama* and *dada* are so often among babies' first words. Of course, even before they produce their first words, children can understand a fair amount of the language they hear. Language comprehension precedes language production.

babble Meaningless, speechlike sounds made by children from around the age of 3 months through 1 year. (Module 25)

A syllable in signed language, similar to the ones seen in the manual babbling of deaf infants and in the spoken babbling of hearing infants. The similarities in language structure suggest that language has biological roots.

Courtesy of Dr. Laura Ann Petitto. Photo by Robert LaMarche

After the age of 1 year, children begin to learn more complicated forms of language. They produce two-word combinations, the building blocks of sentences, and sharply increase the number of different words they are able to use.

By age 2, the average child has a vocabulary of more than 50 words. Just 6 months later, at $2\frac{1}{2}$ years of age, that vocabulary has grown to several hundred words.

Also around the age of 2, children begin to produce short, two-word sentences. However, the sentences children first produce are characterized as telegraphic speech. **Telegraphic speech** consists of sentences in which only essential words are used, usually nouns and verbs only. Rather than saying, "I showed you the book," a child using telegraphic speech may say, "I show book," and "I am drawing a dog" may become "Drawing dog." As children get older, of course, they use less telegraphic speech and produce increasingly complex sentences (Volterra et al., 2003; Pérez-Leroux, Pirvulescu, & Roberge, 2011).

telegraphic speech Sentences in which only essential words are used, typically including only nouns and verbs. (Module 25)

By age 3, children learn to make plurals by adding *-s* to nouns and to form the past tense by adding *-ed* to verbs. However, these skills also lead to speech errors, since children tend to apply rules inflexibly, a process known as overgeneralization. In **overgeneralization,** children employ rules even when doing so results in an error. Thus, although it is correct to say "he walked" for the past tense of *walk*, the *-ed* rule doesn't work quite so well when children say "he runned" for the past tense of *run* (Gershkoff-Stowe, Connell, & Smith, 2006; Kidd & Lum, 2008; Pozzan & Valian, 2017).

overgeneralization The phenomenon by which children over-apply a language rule, thereby making a linguistic error. (Module 25)

By age 5, children have acquired the basic rules of language. However, they do not attain a full vocabulary and the ability to comprehend and use subtle grammatical rules until later. For example, a 5-year-old boy who sees a blindfolded doll and is asked, "Is the doll easy or hard to see?" would have great trouble answering the question. In fact, if he were asked to make the doll easier to see, he would probably try to remove the doll's blindfold. By the time they are 8 years old, however, children have little difficulty understanding this question because they realize that the doll's blindfold has nothing to do with an observer's ability to see the doll (Hoff, 2003; Dockrell & Marshall, 2015).

UNDERSTANDING LANGUAGE ACQUISITION: IDENTIFYING THE ROOTS OF LANGUAGE

Anyone who spends even a little time with children will notice the enormous strides that they make in language development throughout childhood. However, the reasons for this rapid growth are far from obvious. Psychologists have offered three major explanations: one based on learning theory, one based on innate processes, and one that involves something of a combination of the two.

learning-theory approach (to language development) The theory that language acquisition follows the principles of reinforcement and conditioning. (Module 25)

Learning-Theory Approaches: Language as a Learned Skill The **learning-theory approach** suggests that language acquisition follows the principles of reinforcement and conditioning discovered by psychologists who study learning. For example, a child who says "mama" receives hugs and praise from her mother, which reinforce the behavior of saying "mama" and make its repetition more likely. This view suggests that children first learn to speak by being rewarded for making sounds that approximate speech. Ultimately, through a process of shaping, language becomes more and more like adult speech (Skinner, 1957; Ornat & Gallo, 2004).

In support of the learning-theory approach to language acquisition, the more that parents speak to their young children, the more proficient the children become in language use. In addition, by the time they are 3 years old, children who hear higher levels of linguistic sophistication in their parents' speech show a greater rate of vocabulary growth, vocabulary use, and even general intellectual achievement than do children whose parents' speech is simpler (Hart & Risley, 1997).

The learning-theory approach is less successful in explaining how children acquire language rules. Children are reinforced not only when they use language correctly but also when they use it incorrectly. For example, parents answer a child's query of "Why the dog won't eat?" as readily as they do the correctly phrased question, "Why won't

the dog eat?" Listeners understand both sentences equally well. Learning theory, then, has difficulty fully explaining language acquisition.

Nativist Approaches: Language as an Innate Skill Pointing to such problems with learning-theory approaches to language acquisition, linguist Noam Chomsky (1978, 1991) provided a groundbreaking alternative. He argued that humans are born with an innate linguistic capability that emerges primarily as a function of maturation.

According to Chomsky's **nativist approach,** humans are genetically prewired to learn language at certain periods in their lives and in a particular way. Furthermore, he suggests that all the world's languages share a common underlying structure that is prewired, genetically determined, and universal across all people.
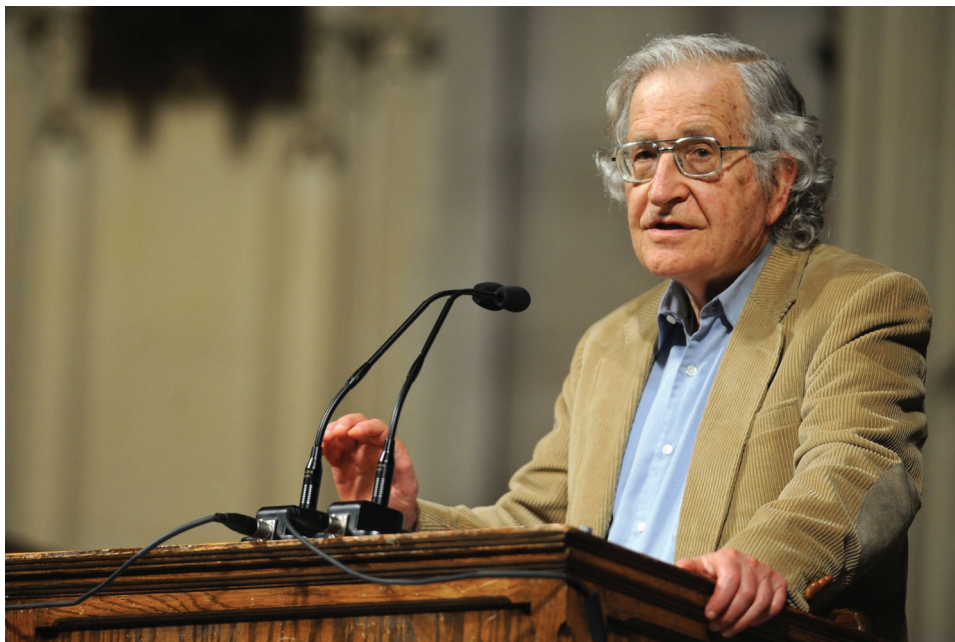
nativist approach (to language development) The theory that humans are genetically prewired to learn language at certain times and in particular ways. (Module 25)

The nativist approach argues that the human brain contains an inherited neural system, which Chomsky calls *universal grammar,* that lets us understand the structure language provides. These inborn capabilities give us strategies and techniques for learning the unique characteristics of our own native language (McGilvray, 2004; White, 2007; Yang et al., 2017).

Evidence collected by neuroscientists supports Chomsky's view. This research suggests that the ability to use language, which was a significant evolutionary advance in human beings, is tied to specific neurological developments. For example, scientists have discovered a gene related to the development of language abilities that may have emerged as recently–in evolutionary terms–as 100,000 years ago.

Furthermore, it is clear that there are specific sites within the brain that are closely tied to language and that the shape of the human mouth and throat are tailored to the production of speech. And there is evidence that features of specific types of languages are tied to particular genes, such as in "tonal" languages in which pitch is used to convey meaning (Grigorenko, 2009; Perovic & Radenovic, 2011; Lieberman, 2015).

However, Chomsky's nativist view is contradicted by some researchers. For instance, learning theorists contend that the apparent ability of certain animals, such as chimpanzees, to learn the fundamentals of human language (as we discuss later in this module) contradicts the innate linguistic capability view. Furthermore, some cognitive psychologists believe that what underlies children's language learning is their use of

Noam Chomsky argues that all languages share a universal grammar.
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general cognitive abilities, as well as skills attained through social interaction with others (Ibbotson & Tomasello, 2016).

interactionist approach (to language development) The view that language development is determined by genetic and social factors, produced through a combination of genetically determined predispositions and the social world in which one is raised. (Module 25)

Interactionist Approaches To reconcile the differing views of the learning-theory and nativist approaches, many theorists hold a compromise view, known as the interactionist approach to language development. The **interactionist approach** suggests that language development is determined by both genetic and social factors, produced through a combination of genetically determined predispositions *and* the social world in which one is raised.

Specifically, proponents of the interactionist approach suggest that the brain is hardwired for our acquisition of language, in essence providing the "hardware" that allows us to develop language. However, it is the exposure to language from social interactions with others that allows us to develop the appropriate "software" to understand and produce language.

The interactionist approach has many proponents. Still, the issue of how language is acquired remains hotly contested (Pinker & Jackendoff, 2005; Hoff, 2008; Waxman, 2009).

Study Alert

It's important to be able to compare and contrast the major approaches to language development: learning-theory, nativist, and interactionist approaches.

From the perspective of . . .

A Child-Care Provider How would you encourage children's language abilities at the different stages of development?

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The Influence of Language on Thinking: Do Eskimos Have More Words for Snow Than Texans Do?

Do Eskimos living in the frigid Arctic have a more expansive vocabulary for discussing snow than people living in warmer climates do?

It makes sense, and arguments that the Eskimo language has many more words than English does for snow have been made since the early 1900s. At that time, linguist Benjamin Lee Whorf contended that because snow is so relevant to Eskimos' lives, their language provides a particularly rich vocabulary to describe it–considerably larger than what we find in other languages, such as English (Martin & Pullum, 1991; Pinker, 1994).

linguistic-relativity hypothesis The hypothesis that language shapes and may determine the way people perceive and understand the world. (Module 25)

The contention that the Eskimo language is especially abundant in snow-related terms led to the linguistic-relativity hypothesis. According to the **linguistic-relativity hypothesis,** language shapes and helps determine the way people perceive and understand the world. That is, language provides us with categories we use to construct our view of others and events in the world around us. In this way, language shapes and produces thought (Whorf, 1956; Tan et al., 2008; Bylund & Athanasopoulos, 2017).

Let's consider another possibility, however. Suppose that instead of language being the *cause* of certain ways of thinking, thought *produces* language. The only reason to expect that Eskimo language might have more words for snow than English does is that snow is considerably more relevant to Eskimos than it is to people in other cultures.

Which view is correct? Most recent research refutes the linguistic-relativity hypothesis and suggests, instead, that thinking produces language. In fact, new analyses of the

Eskimo language suggest that Eskimos have no more words for snow than English speakers do. If one examines the English language closely, one sees that it is hardly impoverished when it comes to describing snow (consider, for example, *sleet, slush, blizzard, dusting,* and *avalanche*).

Still, the linguistic-relativity hypothesis has not been entirely discarded. A newer version of the hypothesis suggests that speech patterns may influence certain aspects of thinking. For example, in some languages, such as English, speakers distinguish between nouns that can be counted (such as "five chairs") and nouns that require a measurement unit to be quantified (such as "a liter of water"). In some other languages, such as the Mayan language called Yucatec, however, all nouns require a measurement unit. In such cultures, people appear to think more closely about what things are made of than do people in cultures in which languages such as English are spoken (Gentner, Goldin, & Goldin-Meadow, 2003; Tsukasaki & Ishii, 2004; Stam, 2015).

Similarly, Russian speakers have more words for light and dark blues and are better able to discriminate shades of blue visually than English speakers. The Icelandic language contains 24 words for types of waves. Furthermore, some tribes say north, south, east, and west instead of left and right, and they have better spatial orientation. And the Piraha language uses terms such as *few* and *many,* rather than specific numbers, and speakers are unable to keep track of exact quantities (Boroditsky, 2010; Fuhrman et al., 2011).

Finally, language seems to foster and support certain kinds of reasoning. In essence, language makes us better able to think in more sophisticated ways, helping us to understand such concepts as cause and effect (Gentner, 2016).

In short, although research does not support the linguistic-relativity hypothesis that language *causes* thought, it is clear that language influences how we think. And, of course, it certainly is the case that thought influences language, suggesting that language and thinking interact in complex ways (Ross, 2004; Thorkildsen, 2006; Proudfoot, 2009).

> **Study Alert**
> The linguistic-relativity hypothesis suggests language leads to thought.

Do Animals Use Language?

One question that has long puzzled psychologists is whether language is uniquely human or if other animals are able to acquire it as well. Many animals communicate with one another in rudimentary forms. For instance, fiddler crabs wave their claws to signal, bees dance to indicate the direction in which food will be found, and certain birds call "*zick, zick*" during courtship and "*kia*" when they are about to fly away. However, researchers have yet to demonstrate conclusively that these animals use true language, which is characterized in part by the ability to produce and communicate new and unique meanings by following a formal grammar.

Psychologists, however, have been able to teach chimps to communicate at surprisingly high levels. For instance, after 4 years of training, a chimp named Washoe learned to make signs for 132 words and combine those signs into simple sentences. Even more impressively, Kanzi, a bonobo (a kind of small chimpanzee), has linguistic skills that some psychologists claim are close to those of a 2-year-old human being. Kanzi's trainers suggest that he can create grammatically sophisticated sentences and can even invent new rules of syntax (Savage-Rumbaugh, Toth, & Schick, 2007; Slocombe, Waller, & Liebal, 2011).

More generally, researchers have found evidence that nonhuman primates use several basic components of human language. For example, they use vocalizations that they modify based on social and other environmental influences, and they take turns communicating about food resources. Furthermore, they have physical structures that allow them to produce vowel sounds similar to human language (Snowdon, 2017).

Despite the languagelike capabilities of primates such as Kanzi, critics contend that the language such animals use still lacks the grammar and the complex and novel constructions of human language. Instead, they maintain that the chimps are displaying a skill no different from that of a dog that learns to lie down on command to get a reward. Furthermore, we lack firm evidence that animals can recognize and

Psychologist and primatologist Sue Savage-Rumbaugh with a primate friend, Kanzi. Does the use of sign language by primates indicate true mastery of language?
©Laurentiu Garofeanu/Barcroft USA/Barcoft Media via Getty Images

respond to the mental states of others of their species, an important aspect of human communication. Consequently, the issue of whether other animals can use language in a way that humans do remains controversial (Beran, Smith, & Perdue, 2013; Crockford, Wittig, & Zuberbühler, 2015; ten Cate, 2017).

Exploring Diversity

Teaching with Linguistic Variety: Bilingual Education

In New York City, nearly half of the students speak a language other than English in their homes, with more than 180 languages represented. Furthermore, 1 in 6 of the city's 1.1 million students is enrolled in some form of bilingual or English as a Second Language instruction.
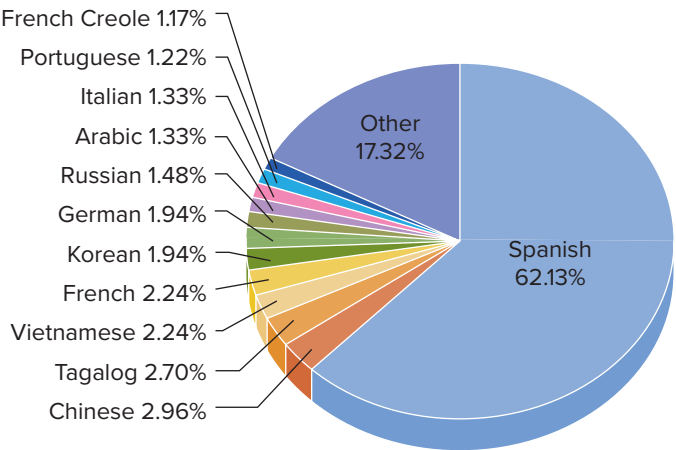
And New York City is far from the only school district with a significant population of nonnative English speakers. From the biggest cities to the most rural areas, the face—and voice—of education in the United States is changing. More and more schoolchildren today have last names like Kim, Valdez, and Karachnicoff. In seven states, including Texas and Colorado, more than one-quarter of the students are not native English speakers. For some 55 million Americans, English is their second language (see Figure 1; Holloway, 2000; Shin & Kominski, 2010).

How to appropriately and effectively teach the increasing number of children who do not speak English is not always clear. Many educators maintain that *bilingual education* is best. With a bilingual approach, students learn some subjects in their native language while simultaneously learning English. Proponents of bilingualism believe that students must develop a sound footing in basic subject areas and that, initially at least, teaching those subjects in their native language is the only way to provide them with that foundation. During the same period, they learn English, with the eventual goal of shifting all instruction into English.

In contrast, other educators insist that all instruction ought to be in English from the moment students, including those who speak no English at all, enroll in school. In *immersion programs,* students are immediately plunged into English instruction in all subjects. The reasoning—endorsed by voters in California in a referendum designed to end bilingual education—is that teaching students in a language other than English simply hinders nonnative English speakers' integration into society and ultimately does them a disservice. Proponents of English immersion programs point as evidence to improvements in standardized test scores that followed the end of bilingual education programs (Wildavsky, 2000).

FIGURE 1 The language of diversity. One-fifth of the people in the United States speak a language other than English at home. Spanish is most prevalent; the rest of non-English speakers use an astounding variety of different languages.
Source: Adapted from MLA. (2010). MLA Language Map; all languages other than English combined. Retrieved from http://www.mla.org/census_map&source=county (based on 2000 U.S. Census Bureau figures).

- French Creole 1.17%
- Portuguese 1.22%
- Italian 1.33%
- Arabic 1.33%
- Russian 1.48%
- German 1.94%
- Korean 1.94%
- French 2.24%
- Vietnamese 2.24%
- Tagalog 2.70%
- Chinese 2.96%
- Other 17.32%
- Spanish 62.13%

Although the controversial issue of bilingual education versus immersion has strong political undercurrents, evidence shows that the ability to speak two languages provides significant cognitive benefits over speaking only one language. For example, bilingual speakers show more cognitive flexibility and may understand concepts more easily than do those who speak only one language. They have more linguistic tools for thinking because of their multiple-language abilities. In turn, this makes them more creative and flexible in solving problems (Kuo, 2007; Yim & Rudoy, 2013; Christoffels et al., 2015).

In addition, the advantages of bilingualism start early: by the time bilingual children are 3 or 4 years old, their cognitive development is superior to that of children who speak only one language. It's an advantage that lasts into old age. In fact, bilingualism provides protection from the cognitive declines that are typical in late adulthood (Bialystok et al., 2010; Bialystok & Craik, 2011; Bialystok, 2011).

Furthermore, speaking several languages changes the organization of the brain. For example, bilingual speakers who learn their second language as adults show different areas of brain activation compared with those who learn their second language in child-hood. And those who are immersed in intensive language instruction show growth in the hippocampus. In addition, brain scans show that people who speak multiple languages have distinct patterns of brain activity according to the language that they are using, and bilingualism produces more efficient processing on some cognitive tasks (Kovacs & Mehler, 2009; Bialystok et al., 2010; Kluger, 2013). (Also see *Neuroscience in Your Life.*)

Related to questions about bilingual education is the matter of *biculturalism*—that is, being a member of two cultures and its psychological impact. Some psychologists argue that society should promote an *alternation model* of bicultural competence. Such a model supports members of a culture in their efforts to maintain their original cultural identity as well as in their integration into the adopted culture. In this view, a person can belong to two cultures and have two cultural identities without having to choose between them. Whether society will adopt the alternation model remains to be seen (Carter, 2003; Benet-Martínez, Lee, & Leu, 2006; Tadmor, 2007).

AP❚ NEUROSCIENCE IN YOUR LIFE: BEING BILINGUAL AFFECTS THE BRAIN

Because it appears increasingly clear that people who are bilingual have certain cognitive advantages, such as greater cognitive flexibility, researchers are now exploring whether being bilingual affects the structure and functioning of the brain. And they have found, for example, that Spanish-English bilingual adults have more grey matter volume in frontal and parietal brain regions than English monolinguals. This can be seen in the two images of the brain below, where the red indicates the areas that have more grey matter volume for bilinguals. The findings suggest that managing the use of two separate languages affects the structure of the brain, potentially affecting its functioning (Olulade et al., 2016).
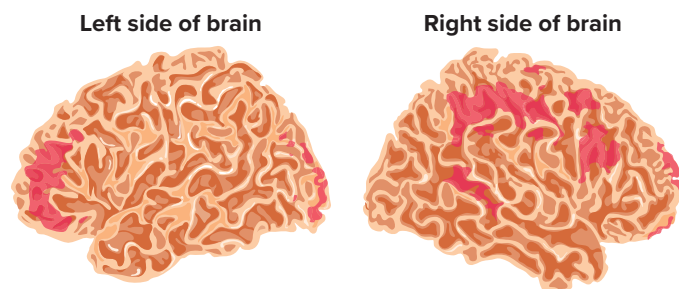
AP SKILL: SCIENTIFIC INVESTIGATION / EXPLAIN BEHAVIOR IN AUTHENTIC CONTEXT

1. Provide a hypothesis for the experiment described.

2. Why might bilinguals have more grey matter volume in the frontal and parietal lobes?

Left side of brain   **Right side of brain**

Source: Adapted from Olulade, O. A., Jamal, N. I., Koo, D. S., Perfetti, C. A., LaSasso, C., & Eden, G. F. (2016). Neuroanatomical evidence in support of the bilingual advantage theory. *Cerebral Cortex, 26*(7), 3196-3204. doi: 10.1093/cercor/bhv152

MODULE 25: LANGUAGE

AP SUMMARY

- Noam Chomsky's nativist approach to language development argues that humans are genetically prewired to learn language at certain periods of their lives and in a specific way. The human brain contains an inherited neural system, called universal grammar, that lets us understand the structure language provides.
- Language is the communication of information through symbols arranged according to systematic rules. All languages have a grammar–a system or structure of rules that determines how thoughts can be expressed–that encompasses the three major components of language: phonology, syntax, and semantics.
- Language production, which follows language comprehension, develops out of babbling, which then leads to the production of actual words. By age 1, children stop producing sounds that are not from the language to which they have been exposed and begin speaking single words. After 1 year of age, children use two-word combinations, increase their vocabulary, and use telegraphic speech, which drops words not critical to the message. By age 3, children being to apply rules inflexibly that result in errors, a process known as overgeneralization. By age 5, acquisition of basic language rules is relatively complete.
- Some theorists argue that a critical period exists for language development early in life in which a child is sensitive to language cues and easily acquires language. Cases involving isolation from contact, such as Genie, support this theory.
- Learning theorists, such as B.F. Skinner, suggest that language is acquired through reinforcement and conditioning. In contrast, the nativist approach suggests that an innate linguistic ability guides the development of language. The interactionist approach argues that language development is produced through a combination of genetically determined predispositions and environmental circumstances that help teach language.
- The linguistic-relativity hypothesis, proposed by Benjamin Lee Whorf, suggests that language shapes and may determine the way people think about the world. Most evidence suggests that although language does not determine thoughts, it does influence it.
- The degree to which language is a uniquely human skill remains an open question. Some psychologists argue that even though certain primates communicate at a high level, those animals do not use language. Other psychologists suggest that those primates truly understand and produce language in much the same way as humans.
- People who speak more than one language may have a cognitive advantage over those who speak only one.

AP KEY TERMS

language
grammar
phonology
phonemes
syntax
semantics
babble
telegraphic speech
overgeneralization
learning-theory approach (to language development)
nativist approach (to language development)
interactionist approach (to language development)
linguistic-relativity hypothesis

AP TEST PRACTICE

Section I: Multiple Choice

1. Who supports the nativist approach to language development?
   A. B.F. Skinner
   B. Wolfgang Köhler
   C. Benjamin Lee Whorf
   D. Noam Chomsky
   E. George Miller

2. As you age it is more challenging to pronounce sounds from a foreign language. Basic units of sound are known as
   A. grammar
   B. morphemes
   C. phonemes
   D. semantics
   E. syntax

3. According to Benjamin Lee Whorf's linguistic-relativity hypothesis, what is the relationship between language and cognition?
   A. Language acquisition follows the principles of reinforcement and conditioning
   B. Language influences how we think
   C. Language is genetically prewired in humans
   D. Language is uniquely human
   E. Language must be learned during a critical period

Section II: Free Response

Researchers conducted an experiment involving a new learning method for a foreign language. Each participant was randomly assigned to one of two conditions. One group of participants was provided an electronic translator to help learn a new language. Another group was provided traditional methods for learning a new language. After six months, both groups were given an oral assessment and received a score from 0–100.

- Provide the independent variable
- Operationally define the dependent variable

- What makes the study experimental rather than correlational?
- What is the control group?

Describe how each of the following relates to language acquisition and age.

- Phonemes
- Universal grammar
- Critical period

LOOKING *Back*

EPILOGUE

The study of cognition occupies a central place in the field of psychology and encompasses a variety of areas—including thinking, problem solving, decision making, creativity, language, memory, and intelligence. Specialists in cognitive psychology have made significant advances in the last decade that have influenced the entire field of psychology.

VISUAL SUMMARY 8 Cognition and Language

MODULES 23 and 24 Thinking, Reasoning, and Problem Solving

Thinking: Brain activity in which people mentally manipulate information, including words, visual images, sounds, or other data

(a)

(b)

(c)
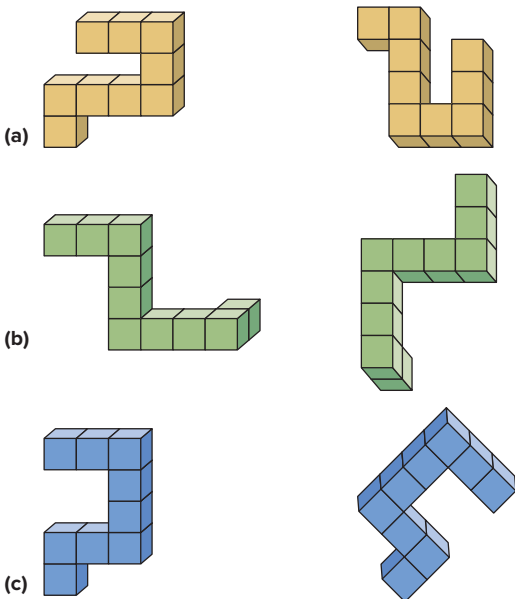
— Mental images: Representations in the mind of an object or event

— Concepts: Categorizations of objects, events, or people that share common properties

— Prototypes: Typical examples of a concept

Concept Category				
Ranking of Prototype	Furniture	Vehicle	Weapon	Vegetable
1—Most Typical	Chair	Car	Gun	Peas
2	Sofa	Truck	Knife	Carrots
3	Table	Bus	Sword	String beans
4	Dresser	Motorcycle	Bomb	Spinach
5	Desk	Train	Hand grenade	Broccoli
6	Bed	Trolley car	Spear	Asparagus
7	Bookcase	Bicycle	Cannon	Corn
8	Footstool	Airplane	Bow and arrow	Cauliflower
9	Lamp	Boat	Club	Brussels sprouts
10	Piano	Tractor	Tank	Lettuce
11	Cushion	Cart	Tear gas	Beets
12	Mirror	Wheelchair	Whip	Tomato
13	Rug	Tank	Ice pick	Lima beans
14	Radio	Raft	Fists	Eggplant
15—Least Typical	Stove	Sled	Rocket	Onion

Reasoning: Drawing a conclusion from a set of assumptions

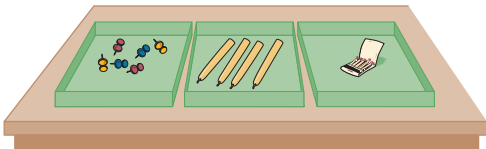— Algorithms: Rules that may guarantee a correct solution

— Heuristics: Cognitive shortcuts that may lead to a solution

Problem Solving: Well-defined and ill-defined problems

Preparation
Understanding and diagnosing problems

Production
Generating solutions

Judgment
Evaluating solutions

— Impediments to problem solving

— Functional fixedness

MODULE 25 Language

Language Development: Acquiring language

— Babbling: Speechlike sounds that are meaningless

— Telegraphic speech: Sentences in which only essential words are used

— Overgeneralization: The phenomenon in which children over-apply a language rule, thereby making a linguistic error

— Approaches to learning language

— Learning-theory approach

— Nativist approach

— Interactionist approach

Linguistic-Relativity Hypothesis: The hypothesis that language shapes and may determine the way people perceive and understand the world