SOME QUESTIONS WE WILL CONSIDER

- How is cognitive psychology relevant to everyday experience? (5)
- How is it possible to study the inner workings of the mind when we can't really see the mind directly? (7)
- What was the cognitive revolution? (13)

It's been 16 years since the accident. Sam, lying in the long-term care facility, has been in a coma ever since. Observing Sam, who shows no signs of awareness or ability to communicate, it seems reasonable to conclude that "there's nobody in there." But is that true? Does the fact that Sam hasn't moved or responded to stimulation mean he doesn't have a mind? Is there any probability that his eyes, which appear to be vacantly staring into space, could be perceiving, and that these perceptions might be accompanied by thoughts?

These are the questions Lorina Naci and coworkers (2014, 2015) were asking when they placed Sam in a brain scanner that measured increases and decreases in electrical activity throughout his brain, and then showed him an 8-minute excerpt from an Alfred Hitchcock television program called "Bang. You're Dead." At the beginning, a 5-year-old boy is playing with his toy gun. But then he discovers a real gun and some bullets in his uncle's suitcase. The boy loads one bullet into the gun, spins the chamber that contains the single bullet, and shoves the weapon into his toy-gun holster.

As the boy roams the neighborhood, pointing the gun at a number of different people, the tension mounts. He points the gun at someone! He pulls the trigger! The gun doesn't fire because the single bullet isn't in the firing chamber. But thoughts such as "Will the gun go off?" and "Will someone be killed?" are racing through the viewers' minds, knowing that the boy's "play" could, at any moment, turn tragic. (There was a reason Hitchcock was called "the master of suspense.") In the last scene, back at the boy's house, the boy's father, realizing that he is pointing a real gun, lunges toward the boy. The gun fires! A mirror shatters. Luckily, no one is hurt. The boy's father grabs the gun, and the audience breathes a sigh of relief.

When this film was shown to healthy participants in the scanner, their brain activity increased and decreased at the same time for all of the participants, with changes in brain activity being linked to what was happening in the movie. Activity was highest at suspenseful moments in the film, such as when the child was loading the gun or pointing it at someone. So the viewer's brains weren't just responding to the images on the screen; their brain activity was being driven both by the images *and* by the movie's plot. And—here's the important point—to understand the plot, it is necessary to understand things that weren't specifically presented in the movie, like "guns are dangerous when loaded," "guns can kill people," and "a 5-year-old boy may not be aware that he could accidentally kill someone."

So, how did Sam's brain respond to the movie? Amazingly, his response was the same as the healthy participants' responses: brain activity increased during periods of tension and decreased when danger wasn't imminent. This indicates that Sam was not only seeing the images and hearing the soundtrack, but that he was reacting to the movie's plot! His brain activity therefore indicated that Sam was consciously aware; that "someone was in there."

This story about Sam, who appears to have a mental life despite appearances to the contrary, has an important message as we embark on the adventure of understanding the mind. Perhaps the most important message is that the mind is hidden from view. Sam is an extreme case because he can't move or talk, but you will see that the "normal" mind also holds many secrets. Just as we can't know exactly what Sam is experiencing, we don't know exactly what other people are experiencing, even though they are able to tell us about their thoughts and observations.

And although you may be aware of your own thoughts and observations, you are unaware of most of what's happening in your mind. This means that as you understand what you are reading right now, there are hidden processes operating within your mind, beneath your awareness, that make this understanding possible.

As you read this book, you will see how research has revealed many of these secret aspects of the mind's operation. This is no trivial thing, because your mind not only makes it possible for you to read this text and understand the plots of movies, but it is responsible for who you are and what you do. It creates your thoughts, perceptions, desires, emotions, memories, language, and physical actions. It guides your decision making and problem solving. It has been compared to a computer, although your brain outperforms your smartphone, laptop, or even a powerful supercomputer on many tasks. And, of course, your mind does something else that computers can't even dream of (if only they could dream!): it creates your consciousness of what's out there, what's going on with your body, and, simply, what it's like to be you!

In this book, we will be describing what the mind is, what it does, and how it does it. The first step in doing this is to look at some of the things the mind does. As we do this, we will see that the mind is multifaceted, involving multiple functions and mechanisms. We begin this chapter by looking at the multifaceted nature of the mind and then describing some of the history behind the field of cognitive psychology.

Cognitive Psychology: Studying the Mind

You may have noticed that we have been using the term *mind* without precisely defining it. As we will see, **mind**, like other concepts in psychology such as intelligence or emotion, can be thought of in a number of different ways.

What Is the Mind?

One way to approach the question "What is the mind?" is to consider how "mind" is used in everyday conversation. Here are a few examples:

1. "He was able to call to mind what he was doing on the day of the accident." (The mind as involved in memory)
2. "If you put your mind to it, I'm sure you can solve that math problem." (The mind as problem-solver)
3. "I haven't made up my mind yet" or "I'm of two minds about this." (The mind as used to make decisions or consider possibilities)
4. "He is of sound mind and body" or "When he talks about his encounter with aliens, it sounds like he is out of his mind." (A healthy mind being associated with normal functioning, a nonfunctioning mind with abnormal functioning)
5. "A mind is a terrible thing to waste." (The mind as valuable, something that should be used)
6. "He has a brilliant mind." (Used to describe people who are particularly intelligent or creative)

These statements tell us some important things about what the mind is. Statements 1, 2, and 3, which highlight the mind's role in memory, problem solving, and making decisions, are related to the following definition of the mind: *The mind creates and controls mental functions such as perception, attention, memory, emotions, language, deciding, thinking, and reasoning.* This definition reflects the mind's central role in determining our various mental abilities, which are reflected in the chapter titles in this book.

Another definition, which focuses on how the mind operates, is this: *The mind is a system that creates representations of the world so that we can act within it to achieve our goals*. This definition reflects the mind's importance for functioning and survival, and also provides the beginnings of a description of how the mind achieves these ends. The idea of creating representations is something we will return to throughout this book.

These two definitions of the mind are not incompatible. The first one indicates different types of **cognition**—the mental processes, such as perception, attention, and memory, which is what the mind creates. The second definition indicates something about how the mind operates (it creates representations) and its function (it enables us to act and to achieve goals). It is no coincidence that all of the cognitions in the first definition play important roles in acting to achieve goals.

Statements 4, 5, and 6 emphasize the mind's importance for normal functioning, and the amazing abilities of the mind. The mind is something to be used, and the products of some people's minds are considered extraordinary. But one of the messages of this book is that the idea that the mind is amazing is not reserved for "extraordinary" minds, because even the most "routine" things—recognizing a person, having a conversation, or deciding what courses to take next semester—become amazing in themselves when we consider the properties of the mind that enable us to achieve these familiar activities.

Cognitive psychology is the study of mental processes, which includes determining the characteristics and properties of the mind and how it operates. Our goals in the rest of this chapter are to describe how the field of cognitive psychology evolved from its early beginnings to where it is today, and to begin describing how cognitive psychologists approach the scientific study of the mind.

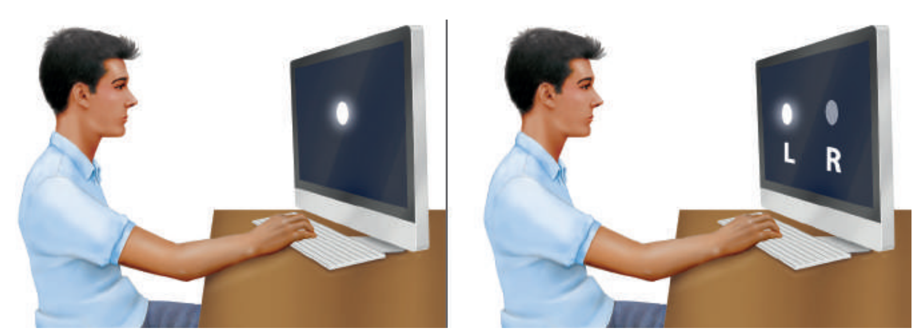
Studying the Mind: Early Work in Cognitive Psychology

In the 1800s, ideas about the mind were dominated by the belief that it is not possible to study the mind. One reason given for this belief was that it is not possible for the mind to study itself, but there were other reasons as well, including the idea that the properties of the mind simply cannot be measured. Nonetheless, some researchers defied the common wisdom and decided to study the mind anyway. One of these people was the Dutch physiologist Franciscus Donders, who in 1868, 11 years before the founding of the first laboratory of scientific psychology, did one of the first experiments that today would be called a cognitive psychology experiment. (It is important to note that the term *cognitive psychology* was not coined until 1967, but the early experiments we are going to describe qualify as cognitive psychology experiments.)

Donders's Pioneering Experiment: How Long Does It Take to Make a Decision?

Donders was interested in determining how long it takes for a person to make a decision. He determined this by measuring **reaction time**—how long it takes to respond to presentation of a stimulus. He used two measures of reaction time. He measured **simple reaction time** by asking his participants to push a button as rapidly as possible when they saw a light go on (**Figure 1.1a**). He measured **choice reaction time** by using two lights and asking his participants to push the left button when they saw the left light go on and the right button when they saw the right light go on (**Figure 1.1b**).

The steps that occur in the simple reaction time task are shown in **Figure 1.2a**. Presenting the stimulus (the light flashes) causes a mental response (perceiving the light), which leads to a behavioral response (pushing the button). The reaction time (dashed line) is the time between the presentation of the stimulus and the behavioral response.

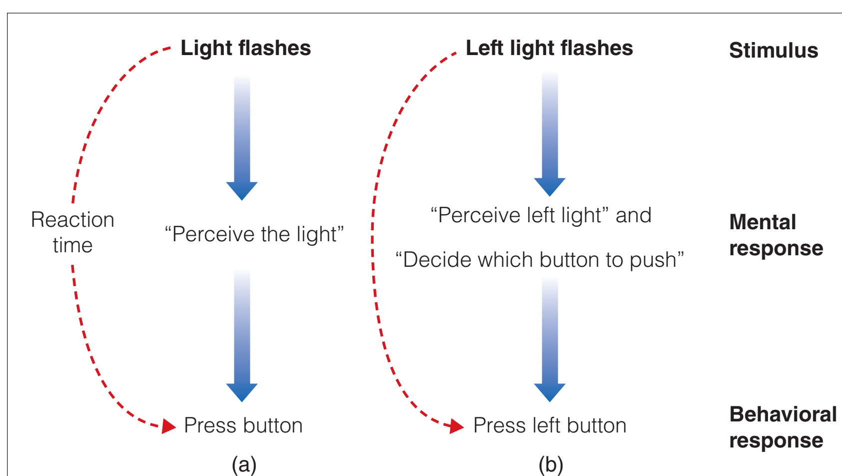


(a) Press J when light goes on.
(b) Press J for left light, K for right.

➤ **Figure 1.1** A modern version of Donders's (1868) reaction time experiment: (a) the simple reaction time task and (b) the choice reaction time task. In the simple reaction time task, the participant pushes the J key when the light goes on. In the choice reaction time task, the participant pushes the J key if the left light goes on and the K key if the right light goes on. The purpose of Donders's experiment was to determine how much time it took to decide which key to press in the choice reaction time task.

But remember that Donders was interested in determining how long it took for a person to make a decision. The choice reaction time task added decisions by requiring participants to first decide whether the left or right light was illuminated and then which button to push. The diagram for this task, in **Figure 1.2b**, changes the mental response to "Perceive left light" and "Decide which button to push." Donders reasoned that the difference in reaction time between the simple and choice conditions would indicate how long it took to make the decision that led to pushing the correct button. Because the choice reaction time took one-tenth of a second longer than simple reaction time, Donders concluded that the decision-making process took one-tenth of a second.

Donders's experiment is important, both because it was one of the first cognitive psychology experiments and because it illustrates something extremely significant about studying the mind: Mental responses (perceiving the light and deciding which button to push, in this example) cannot be measured directly, but must be inferred from behavior. We can see why this is so by noting the dashed lines in Figure 1.2. These lines indicate that when Donders measured reaction time, he was measuring the relationship between presentation of the stimulus and the participant's response. He did not measure mental responses directly, but inferred how long they took from the reaction times. The fact that mental responses cannot be measured directly, but must be inferred from observing behavior, is a principle that holds not only for Donders's experiment but for all research in cognitive psychology.



➤ **Figure 1.2** Sequence of events between presentation of the stimulus and the behavioral response in Donders's experiments: (a) simple reaction time task and (b) choice reaction time task. The dashed line indicates that Donders measured reaction time—the time between presentation of the light and the participant's response.

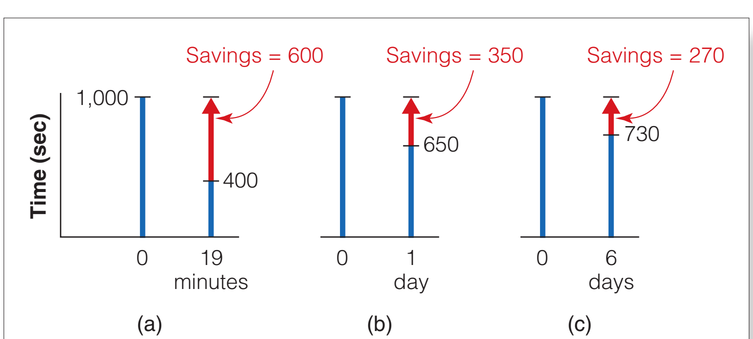
Wundt's Psychology Laboratory: Structuralism and Analytic Introspection In 1879, 11 years after Donders's reaction time experiment, Wilhelm Wundt founded the first laboratory of scientific psychology at the University of Leipzig in Germany. Wundt's approach, which dominated psychology in the late 1800s and early 1900s, was called **structuralism**. According to structuralism, our overall experience is determined by combining basic elements of experience the structuralists called *sensations*. Thus, just as chemistry developed a periodic table of the elements, which combine to create molecules, Wundt wanted to create a "periodic table of the mind," which would include all of the basic sensations involved in creating experience.

Wundt thought he could achieve this scientific description of the components of experience by using **analytic introspection**, a technique in which trained participants described their experiences and thought processes in response to stimuli. Analytic introspection required extensive training because the participants' goal was to describe their experience in terms of elementary mental elements. For example, in one experiment, Wundt asked participants to describe their experience of hearing a five-note chord played on the piano. One of the questions Wundt hoped to answer was whether his participants were able to hear each of the individual notes that made up the chord. As we will see when we consider perception in Chapter 3, structuralism was not a fruitful approach and so was abandoned in the early 1900s. Nonetheless, Wundt made a substantial contribution to psychology by his commitment to studying behavior and the mind under controlled conditions. In addition, he trained many PhDs who established psychology departments at other universities, including many in the United States.

Ebbinghaus's Memory Experiment: What Is the Time Course of Forgetting?

Meanwhile, 120 miles from Leipzig, at the University of Berlin, German psychologist Hermann Ebbinghaus (1885/1913) was using another approach to measuring the properties of the mind. Ebbinghaus was interested in determining the nature of memory and forgetting—specifically, how rapidly information that is learned is lost over time. Rather than using Wundt's method of analytic introspection, Ebbinghaus used a quantitative method for measuring memory. Using himself as the participant, he repeated lists of 13 nonsense syllables such as DAX, QEH, LUH, and ZIF to himself one at a time at a constant rate. He used nonsense syllables so that his memory would not be influenced by the meaning of a particular word.

Ebbinghaus determined how long it took to learn a list for the first time. He then waited for a specific amount of time (the delay) and then determined how long it took to relearn the list. Because forgetting had occurred during the delay, Ebbinghaus made errors when he first tried to remember the list. But because he had retained something from his original learning, he relearned the list more rapidly than when he had learned it for the first time.



➤ **Figure 1.3** Calculating the savings score in Ebbinghaus's experiment. In this example, it took 1,000 seconds to learn the list of nonsense syllables for the first time. This is indicated by the lines at 0. The time needed to relearn the list at delays of (a) 19 minutes, (b) 1 day, and (c) 6 days are indicated by the line to the right of the 0 line. The red arrows indicate the savings score for each delay. Notice that savings decrease for longer delays. This decrease in savings provides a measure of forgetting.

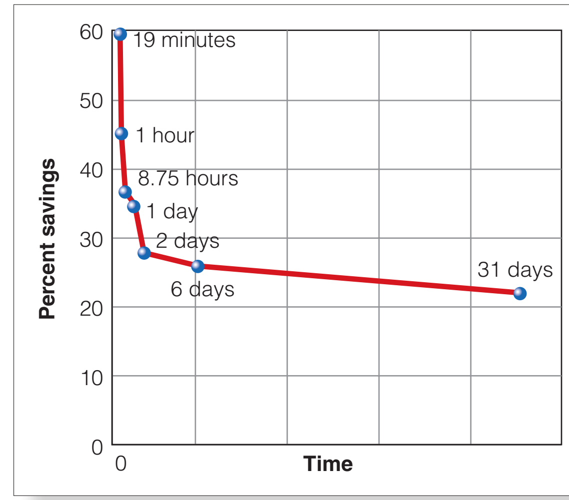
Ebbinghaus used a measure called **savings**, calculated as follows, to determine how much was forgotten after a particular delay: Savings = (Original time to learn the list) − (Time to relearn the list after the delay). Thus, if it took 1,000 seconds to learn the list the first time and 400 seconds to relearn the list after the delay, the savings would be 1,000 − 400 = 600 seconds. **Figure 1.3**, which represents original learning and relearning after three different delays, shows that longer delays result in smaller savings.

According to Ebbinghaus, this reduction in savings provided a measure of forgetting, with smaller savings meaning more forgetting. Thus, the plot of percent savings versus time in **Figure 1.4**, called a **savings curve**, shows that memory drops rapidly for the first 2 days after the initial learning and then levels off. This curve was important because it demonstrated that memory could be quantified and that functions like the savings curve could be used to describe a property of the mind—in this case, the ability to retain information. Notice that although Ebbinghaus's savings method was very different from Donders's reaction time method, both measured behavior to determine a property of the mind.

William James's *Principles of Psychology* William James, one of the early American psychologists (although not a student of Wundt's), taught Harvard's first psychology course and made significant observations about the mind in his textbook, *Principles of Psychology* (1890). James's observations were based not on the results of experiments but on observations about the operation of his own mind. One of the best known of James's observations is the following, on the nature of attention:

> Millions of items . . . are present to my senses which never properly enter my experience. Why? Because they have no interest for me. My experience is what I agree to attend to. . . . Everyone knows what attention is. It is the taking possession by the mind, in clear and vivid form, of one out of what seem several simultaneously possible objects or trains of thought. . . . It implies withdrawal from some things in order to deal effectively with others.

The observation that paying attention to one thing involves withdrawing from other things still rings true today and has been the topic of many modern studies of attention. As impressive as the accuracy of James's observations, so too was the range of cognitive topics he considered, which included thinking, consciousness, attention, memory, perception, imagination, and reasoning.



➤ **Figure 1.4** Ebbinghaus's savings curve. Ebbinghaus considered the percent savings to be a measure of the amount remembered, so he plotted this versus the time between initial learning and testing. The decrease in savings (remembering) with increasing delays indicates that forgetting occurs rapidly over the first 2 days and then occurs more slowly after that.

(Source: Based on data from Ebbinghaus, 1885/1913.)

The founding of the first laboratory of psychology by Wundt, the quantitative experiments of Donders and Ebbinghaus, and the perceptive observations of James provided what seemed to be a promising start to the study of the mind (**Table 1.1**). However, research on the mind was soon to be curtailed, largely because of events early in the 20th century that shifted the focus of psychology away from the study of the mind and mental processes. One of the major forces that caused psychology to reject the study of mental processes was a negative reaction to Wundt's technique of analytic introspection.

TABLE 1.1

Early Pioneers in Cognitive Psychology

Person	Procedure	Results and Conclusions	Contribution
Donders (1868)	Simple reaction time versus choice reaction time	Choice reaction time takes 1/10 seconds longer; therefore, it takes 1/10 second to make a decision	First cognitive psychology experiment
Wundt (1879)	Analytic introspection	No reliable results	Established the first laboratory of scientific psychology
Ebbinghaus (1885)	Savings method to measure forgetting	Forgetting occurs rapidly in the first 1 to 2 days after original learning	Quantitative measurement of mental processes
James (1890)	No experiments; reported observations of his own experience	Descriptions of a wide range of experiences	First psychology textbook; some of his observations are still valid today

Abandoning the Study of the Mind

Many early departments of psychology conducted research in the tradition of Wundt's laboratory, using analytic introspection to analyze mental processes. This emphasis on studying the mind was to change, however, because of the efforts of John Watson, who received his PhD in psychology in 1904 from the University of Chicago.

Watson Founds Behaviorism

The story of how John Watson founded an approach to psychology called **behaviorism** is well known to introductory psychology students. We will briefly review it here because of its importance to the history of cognitive psychology.

As a graduate student at the University of Chicago, Watson became dissatisfied with the method of analytic introspection. His problems with this method were (1) it produced extremely variable results from person to person, and (2) these results were difficult to verify because they were interpreted in terms of invisible inner mental processes. In response to what he perceived to be deficiencies in analytic introspection, Watson proposed a new approach called behaviorism. One of Watson's papers, "Psychology As the Behaviorist Views It," set forth the goals of this approach to psychology in this famous quote:

> Psychology as the Behaviorist sees it is a purely objective, experimental branch of natural science. Its theoretical goal is the prediction and control of behavior. Introspection forms no essential part of its methods, nor is the scientific value of its data dependent upon the readiness with which they lend themselves to interpretation in terms of consciousness. . . . What we need to do is start work upon psychology making behavior, not consciousness, the objective point of our attack. (Watson, 1913, pp. 158, 176; emphasis added)

This passage makes two key points: (1) Watson rejects introspection as a method, and (2) observable behavior, not consciousness (which would involve unobservable processes such as thinking, emotions, and reasoning), is the main topic of study. In other words, Watson wanted to restrict psychology to behavioral data, such as Donders's reaction times, and rejected the idea of going beyond those data to draw conclusions about unobservable mental events. Watson eliminated the mind as a topic for investigation by proclaiming that "psychology . . . need no longer delude itself into thinking that it is making mental states the object of observation" (p. 163). Watson's goal was to replace the mind as a topic of study in psychology with the study of directly observable behavior. As behaviorism became the dominant force in American psychology, psychologists' attention shifted from asking "What does behavior tell us about the mind?" to "What is the relation between stimuli in the environment and behavior?"

Watson's most famous experiment was the "Little Albert" experiment, in which Watson and Rosalie Rayner (1920) subjected Albert, a 9-month-old-boy, to a loud noise every time a rat (which Albert had originally liked) came close to the child. After a few pairings of the noise with the rat, Albert reacted to the rat by crawling away as rapidly as possible.

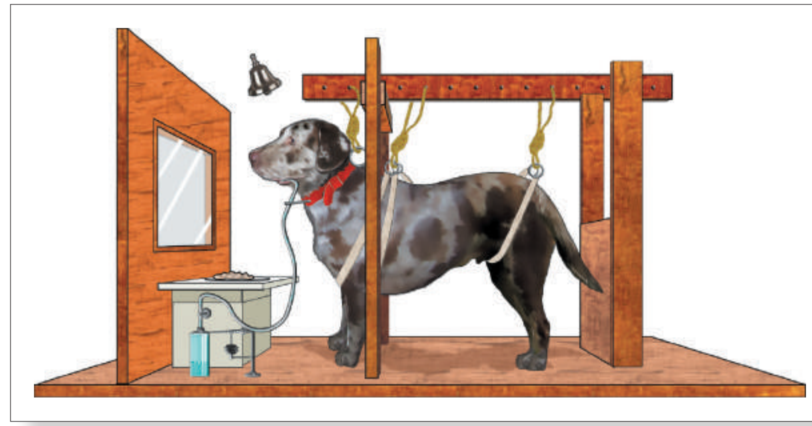
Watson's ideas are associated with **classical conditioning**—how pairing one stimulus (such as the loud noise presented to Albert) with another, previously neutral stimulus (such as the rat) causes changes in the response to the neutral stimulus. Watson's inspiration for his experiment was Ivan Pavlov's research, begun in the 1890s, that demonstrated classical conditioning in dogs. In these experiments (**Figure 1.5**), Pavlov's pairing of food (which made the dog salivate) with a bell (the initially neutral stimulus) caused the dog to salivate to the sound of the bell (Pavlov, 1927).

Watson used classical conditioning to argue that behavior can be analyzed without any reference to the mind. For Watson, what was going on inside Albert's head (or inside

Pavlov's dog's head!), either physiologically or mentally, was irrelevant. He cared only about how pairing one stimulus with another affected behavior.

Skinner's Operant Conditioning

In the midst of behaviorism's dominance of American psychology, B. F. Skinner, who received his PhD from Harvard in 1931, provided another tool for studying the relationship between stimulus and response, which ensured that this approach would dominate psychology for decades to come. Skinner introduced **operant conditioning**, which focused on how behavior is strengthened by the presentation of positive reinforcers, such as food or social approval (or withdrawal of negative reinforcers, such as a shock or social rejection). For example, Skinner showed that reinforcing a rat with food for pressing a bar maintained or increased the rat's rate of bar pressing. Like Watson, Skinner was not interested in what was happening in the mind, but focused solely on determining how behavior was controlled by stimuli (Skinner, 1938).

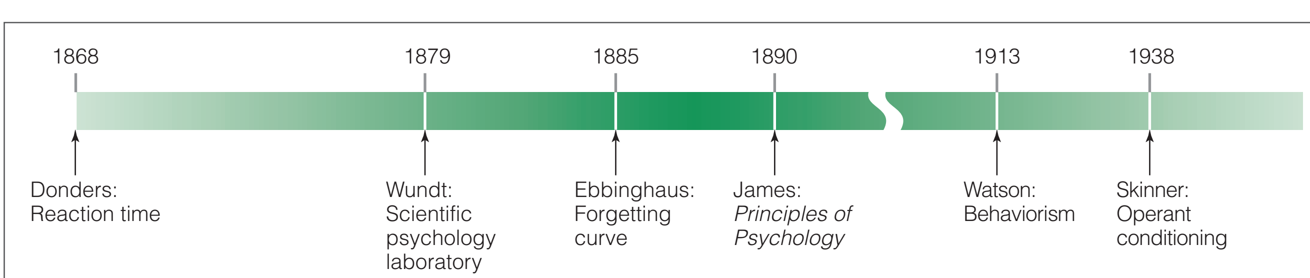


➤ **Figure 1.5** In Pavlov's famous experiment, he paired ringing a bell with presentation of food. Initially, presentation of the food caused the dog to salivate, but after a number of pairings of bell and food, the bell alone caused salivation. This principle of learning by pairing, which came to be called *classical conditioning*, was the basis of Watson's "Little Albert" experiment.

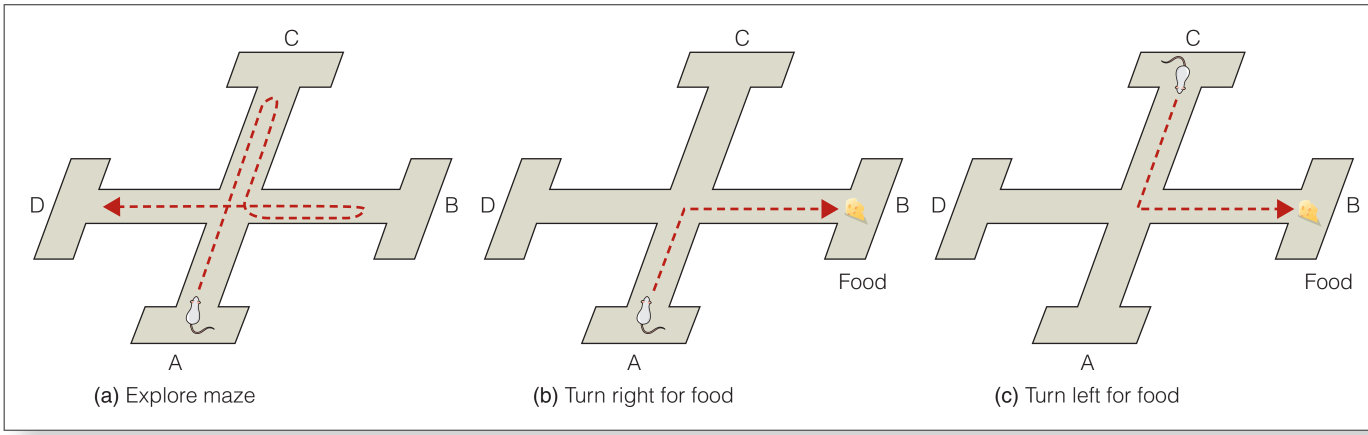
The idea that behavior can be understood by studying stimulus–response relationships influenced an entire generation of psychologists and dominated psychology in the United States from the 1940s through the 1960s. Psychologists applied the techniques of classical and operant conditioning to classroom teaching, treating psychological disorders, and testing the effects of drugs on animals. **Figure 1.6** is a time line showing the initial studies of the mind and the rise of behaviorism. But even as behaviorism was dominating psychology, events were occurring that were to lead to the rebirth of the study of the mind.

Setting the Stage for the Reemergence of the Mind in Psychology

Although behaviorism dominated American psychology for many decades, some researchers were not toeing the strict behaviorist line. One of these researchers was Edward Chace Tolman. Tolman, who from 1918 to 1954 was at the University of California at Berkeley, called himself a behaviorist because his focus was on measuring behavior. But in reality, he was one of the early cognitive psychologists, because he used behavior to infer mental processes.



➤ **Figure 1.6** Time line showing early experiments studying the mind in the 1800s and the rise of behaviorism in the 1900s.



➤ **Figure 1.7** Maze used by Tolman. (a) The rat initially explores the maze. (b) The rat learns to turn right to obtain food at B when it starts at A. (c) When placed at C, the rat turns left to reach the food at B. In this experiment, precautions are taken to prevent the rat from knowing where the food is based on cues such as smell.

In one of his experiments, Tolman (1938) placed a rat in a maze like the one in **Figure 1.7**. Initially, the rat explored the maze, running up and down each of the alleys (**Figure 1.7a**). After this initial period of exploration, the rat was placed at point A and food was placed at point B, and the rat quickly learned to turn right at the intersection to obtain the food. This is exactly what the behaviorists would predict, because turning right was rewarded with food (**Figure 1.7b**). However, when Tolman (after taking precautions to be sure the rat couldn't determine the location of the food based on smell) placed the rat at point C, something interesting happened. The rat turned left at the intersection to reach the food at point B (**Figure 1.7c**). Tolman's explanation of this result was that when the rat initially experienced the maze it was developing a **cognitive map**—a conception within the rat's mind of the maze's layout (Tolman, 1948). Thus, even though the rat had previously been rewarded for turning right, its mental map indicated that when starting from the new location it needed to turn left to reach the food. Tolman's use of the word *cognitive*, and the idea that something other than stimulus–response connections might be occurring in the rat's mind, placed Tolman outside of mainstream behaviorism.

Other researchers were aware of Tolman's work, but for most American psychologists in the 1940s, the use of the term *cognitive* was difficult to accept because it violated the behaviorists' idea that internal processes, such as thinking or maps in the head, were not acceptable topics to study. It wasn't until about a decade after Tolman introduced the idea of cognitive maps that developments occurred that led to a resurgence of the mind in psychology. Ironically, one of these developments was the publication, in 1957, of a book by B. F. Skinner titled *Verbal Behavior*.

In his book, Skinner argued that children learn language through operant conditioning. According to this idea, children imitate speech that they hear, and repeat correct speech because it is rewarded. But in 1959, Noam Chomsky, a linguist from the Massachusetts Institute of Technology, published a scathing review of Skinner's book, in which he pointed out that children say many sentences that have never been rewarded by parents ("I hate you, Mommy," for example), and that during the normal course of language development, they go through a stage in which they use incorrect grammar, such as "the boy hitted the ball," even though this incorrect grammar may never have been reinforced.

Chomsky saw language development as being determined not by imitation or reinforcement, but by an inborn biological program that holds across cultures. Chomsky's idea that language is a product of the way the mind is constructed, rather than a result of reinforcement, led psychologists to reconsider the idea that language and other complex behaviors, such as problem solving and reasoning, can be explained by operant conditioning. Instead, they began to realize that to understand complex cognitive behaviors, it is necessary not only to measure observable behavior but also to consider what this behavior tells us about how the mind works.

The Rebirth of the Study of the Mind

The decade of the 1950s is generally recognized as the beginning of the **cognitive revolution**—a shift in psychology from the behaviorist's focus on stimulus–response relationships to an approach whose main thrust was to understand the operation of the mind. Even before Chomsky's critique of Skinner's book, other events were happening that signaled a shift away from focusing only on behavior and toward studying how the mind operates. But before we describe the events that began the cognitive revolution, let's consider the following question: What is a revolution—and specifically a scientific revolution? One answer to this question can be found in philosopher Thomas Kuhn's (1962) book *The Structure of Scientific Revolutions*.

Paradigms and Paradigm Shifts

Kuhn defined a **scientific revolution** as a shift from one paradigm to another, where a **paradigm** is a system of ideas that dominate science at a particular time (Dyson, 2012). A scientific revolution, therefore, involves a **paradigm shift**.

An example of a paradigm shift in science is the shift that occurred in physics in the beginning of the 20th century, with the introduction of the theory of relativity and quantum theory. Before the 20th century, classical physics, founded by Isaac Newton (1642–1727), had made great progress in describing things like how objects are affected by forces (Newton's laws of motion) and the nature of electrical fields (Maxwell's laws, which described electromagnetism). The principles of classical physics did not, however, adequately describe subatomic phenomena and the relation between time and motion. For example, classical physics conceived of the flow of time as an absolute constant, which was the same for everyone. But in 1905, Albert Einstein, a young clerk in the Bern, Switzerland, patent office, published his theory of relativity, which proposed that the measurement of space and time are affected by an observer's motion, so clocks run slower when approaching the speed of light. He also proposed that there is an equivalence of mass and energy, as expressed in his famous equation E = mc2 (energy equals mass times the speed of light squared). Einstein's relativity theory, along with the newly introduced quantum theory, which explained the behavior of subatomic particles, marked the beginning of modern physics.

Just as the paradigm shift from classical physics to modern physics provided a new way of looking at the physical world, the paradigm shift from behaviorism to the cognitive approach provided a new way to look at behavior. During the reign of behaviorism, behavior was considered an end in itself. Psychology was dominated by experiments studying how behavior is affected by rewards and punishments. Some valuable discoveries resulted from this research, including psychological therapies called "behavioral therapies," which are still in use today. But the behaviorist paradigm did not allow any consideration of the mind's role in creating behavior, so in the 1950s the new cognitive paradigm began to emerge. We can't mark the beginning of this new paradigm by the publication of a single paper, like Einstein's (1905) proposal of relativity theory, but rather we can note a series of events, which added together culminated in a new way of studying psychology. One of these events was the introduction of a new technology that suggested a new way of describing the operation of the mind. That new technology was the digital computer.

Introduction of the Digital Computer

The first digital computers, developed in the late 1940s, were huge machines that took up entire buildings, but in 1954 IBM introduced a computer that was available to the general public. These computers were still extremely large compared to the laptops of today, but they found their way into university research laboratories, where they were used both to analyze data and, most important for our purposes, to suggest a new way of thinking about the mind.

Flow Diagrams for Computers One of the characteristics of computers that captured the attention of psychologists in the 1950s was that they processed information in stages, as illustrated in **Figure 1.8a**. In this diagram, information is first received by an "input processor." It is then stored in a "memory unit" before it is processed by an "arithmetic unit," which then creates the computer's output. Using this stage approach as their inspiration, some psychologists proposed the **information-processing approach** to studying the mind—an approach that traces sequences of mental operations involved in cognition. According to the information-processing approach, the operation of the mind can be described as occurring in a number of stages. Applying this stage approach to the mind led psychologists to ask new questions and to frame their answers to these questions in new ways. One of the first experiments influenced by this new way of thinking about the mind involved studying how well people are able to focus their attention on some information when other information is being presented at the same time.

Flow Diagrams for the Mind Beginning in the 1950s, a number of researchers became interested in describing how well the mind can deal with incoming information. One question they were interested in answering followed from William James's idea that when we decide to attend to one thing, we must withdraw from other things. Taking this idea as a starting point, British psychologist Colin Cherry (1953) presented participants with two auditory messages, one to the left ear and one to the right ear, and told them to focus their attention on one of the messages (the attended message) and to ignore the other one (the unattended message). For example, the participant might be told to attend to the left-ear message that began "As Susan drove down the road in her new car . . ." while simultaneously receiving, but not attending to, the right-ear message "Cognitive psychology, which is the study of mental processes . . ."

The result of this experiment, which we will describe in detail when we discuss attention in Chapter 4, was that when people focused on the attended message, they could hear the sounds of the unattended message but were unaware of the contents of that message. This result led another British psychologist, Donald Broadbent (1958), to propose the first flow diagram of the mind (**Figure 1.8b**). This diagram represents what Broadbent believed happens in a person's mind when directing attention to one stimulus in the environment. Applied to Cherry's attention experiment, "input" would be the sounds of both the attended and unattended messages; the "filter" lets through the attended message and filters out the unattended message; and the "detector" records the information that gets through the filter.

Applied to your experience when talking to a friend at a noisy party, the filter lets in your friend's conversation and filters out all the other conversations and noise. Thus, although you might be aware that there are other people talking, you are not aware of detailed information such as what the other people are talking about.

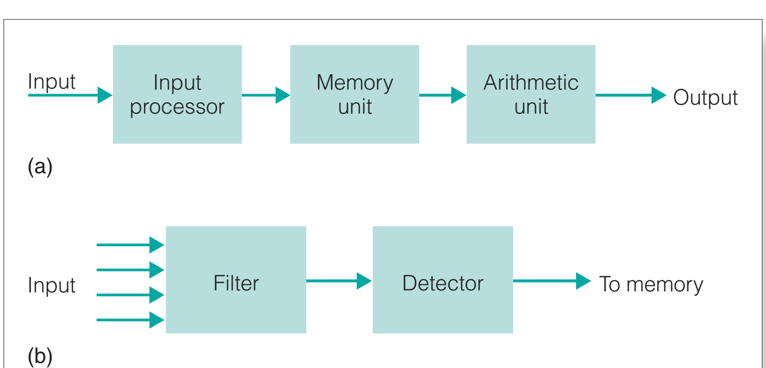


Figure 1.8 (a) Flow diagram for an early computer. (b) Flow diagram for Broadbent's filter model of attention. This diagram shows many messages entering a "filter," which selects the message to which the person is attending for further processing by a detector and then transfer to short-term memory. We will describe this diagram more fully in Chapter 4.

Broadbent's flow diagram provided a way to analyze the operation of the mind in terms of a sequence of processing stages and proposed a model that could be tested by further experiments. You will see many more flow diagrams like this throughout this book because they have become one of the standard ways of depicting the operation of the mind. But the British psychologists Cherry and Broadbent weren't the only researchers finding new ways of studying the mind. At about the same time in the United States, researchers organized two conferences that, taking their cue from computers, conceived of the mind as a processor of information.

Conferences on Artificial Intelligence and Information Theory

In the early 1950s, John McCarthy, a young professor of mathematics at Dartmouth College, had an idea. Would it be possible, McCarthy wondered, to program computers to mimic the operation of the human mind? Rather than simply asking the question, McCarthy decided to organize a conference at Dartmouth in the summer of 1956 to provide a forum for researchers to discuss ways that computers could be programmed to carry out intelligent behavior. The title of the conference, *Summer Research Project on Artificial Intelligence*, was the first use of the term **artificial intelligence**. McCarthy defined the artificial intelligence approach as "making a machine behave in ways that would be called intelligent if a human were so behaving" (McCarthy et al., 1955).

Researchers from a number of different disciplines—psychologists, mathematicians, computer scientists, linguists, and experts in information theory—attended the conference, which spanned 10 weeks. A number of people attended most of the conference, others dropped in and out, but perhaps the two most important participants—Herb Simon and Alan Newell from the Carnegie Institute of Technology—were hardly there at all (Boden, 2006). The reason they weren't there is that they were busy back in Pittsburgh trying to create the artificial intelligence machine that McCarthy had envisioned. Simon and Newell's goal was to create a computer program that could create proofs for problems in logic—something that up until then had only been achieved by humans.

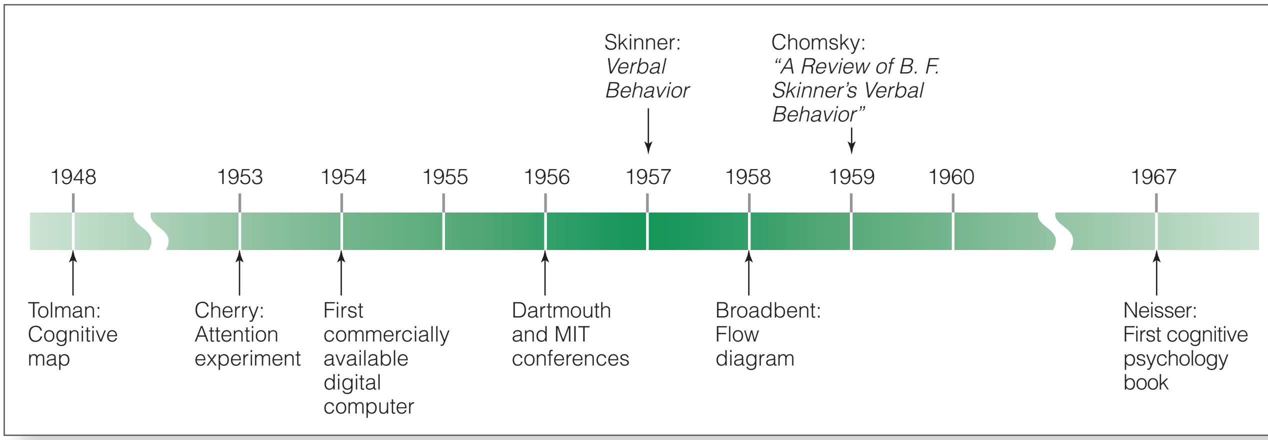
Newell and Simon succeeded in creating the program, which they called the *logic theorist*, in time to demonstrate it at the conference. What they demonstrated was revolutionary because the logic theorist program was able to create proofs of mathematical theorems that involve principles of logic. This program, although primitive compared to modern artificial intelligence programs, was a real "thinking machine" because it did more than simply process numbers—it used humanlike reasoning processes to solve problems.

Shortly after the Dartmouth conference, in September of the same year, another pivotal conference was held, the *Massachusetts Institute of Technology Symposium on Information Theory*. This conference provided another opportunity for Newell and Simon to demonstrate their logic theorist program, and the attendees also heard George Miller, a Harvard psychologist, present a version of a paper "The Magical Number Seven Plus or Minus Two," which had just been published (Miller, 1956). In that paper, Miller presented the idea that there are limits to a human's ability to process information—that the capacity of the human mind is limited to about seven items (for example, the length of a telephone number).

As we will see when we discuss this idea in Chapter 5, there are ways to increase our ability to take in and remember information (for example, we have little trouble adding an area code to the seven digits of many telephone numbers). Nonetheless, Miller's basic principle that there are limits to the amount of information we can take in and remember was an important idea, which, you might notice, was similar to the point being made by Broadbent's filter model at about the same time.

The Cognitive "Revolution" Took a While

The events we have described—Cherry's experiment, Broadbent's filter model, and the two conferences in 1956—represented the beginning of a shift in psychology from behaviorism to the study of the mind. Although we have called this shift the *cognitive revolution*, it is



➤ **Figure 1.9** Time line showing events associated with the decline of the influence of behaviorism (above the line) and events that led to the development of the information-processing approach to cognitive psychology (below the line).

worth noting that the shift from Skinner's behaviorism to the cognitive approach, which was indeed revolutionary, occurred over a period of time. The scientists attending the conferences in 1956 had no idea that these conferences would, years later, be seen as historic events in the birth of a new way of thinking about the mind or that scientific historians would someday call 1956 "the birthday of cognitive science" (Bechtel et al., 1998; Miller, 2003; Neisser, 1988). In fact, even years after these meetings, a textbook on the history of psychology made no mention of the cognitive approach (Misiak & Sexton, 1966), and it wasn't until 1967 that Ulrich Neisser published a textbook with the title *Cognitive Psychology* (Neisser, 1967). **Figure 1.9** shows a time line of some of the events that led to the establishment of the field of cognitive psychology.

Neisser's textbook, which coined the term *cognitive psychology* and emphasized the information-processing approach to studying the mind, is, in a sense, the grandfather of the book you are now reading. As often happens, each successive generation creates new ways of approaching problems, and cognitive psychology has been no exception. Since the 1956 conferences and the 1967 textbook, many experiments have been carried out, new theories proposed, and new techniques developed; as a result, cognitive psychology, and the information-processing approach to studying the mind, has become one of the dominant approaches in psychology.

The Evolution of Cognitive Psychology

We have been describing the events in the 1950s and 1960s as the cognitive revolution. But it is important to realize that although the revolution made it acceptable to study the mind, the field of cognitive psychology continued to evolve in the decades that followed. One way to appreciate how cognitive psychology has evolved from the 1950s and 1960s until today is to look at the contents of Neisser's (1967) book.

What Neisser Wrote

We can appreciate where cognitive psychology was in the 1960s by looking at the first cognitive psychology textbook, Ulrich Neisser's (1967) *Cognitive Psychology*. The purpose of this book, as Neisser states in Chapter 1, is "to provide a useful and current assessment of the existing state of the art" (p. 9). Given this purpose, it is instructive to consider the book's Table of Contents.

Most of the book is devoted to vision and hearing. There are descriptions of how information is taken in by vision and held in memory for short periods of time, and how people search for visual information and use visual information to see simple patterns. Most of the discussion is about the intake of information and holding information in the mind for brief periods of time, such as how long people can remember sounds like strings of numbers. But it isn't until page 279 of the 305-page book that Neisser considers "higher mental processes" such as thinking, problem solving, and long-term remembering. The reason Neisser gives for this scant treatment is that in 1967, we just didn't know much about higher mental processes.

Another gap in coverage is the almost complete absence of physiology. Neisser says that "I do not doubt that human behavior and consciousness depends entirely on the activity of the brain and related processes" (p. 5), but then he goes on to argue that he is interested in how the mind operates, but not in the physiological mechanisms behind this operation.

These two gaps in Neisser's book highlight what are central topics in present-day cognitive psychology. One of these topics is the study of higher mental processes, and the other is the study of the physiology of mental processes.

Studying Higher Mental Processes

A big step toward the study of higher mental processes was Richard Atkinson and Richard Shiffrin's (1968) model of memory, which was introduced a year after the publication of Neisser's book. This model, shown in **Figure 1.10**, pictures the flow of information in the memory system as progressing through three stages. *Sensory memory* holds incoming information for a fraction of a second and then passes most of this information to *short-term memory*, which has limited capacity and holds information for seconds (like an address you are trying to remember until you can write it down). The curved arrow represents the process of rehearsal, which occurs when we repeat something, like a phone number, to keep from forgetting it. The blue arrow indicates that some information in short-term memory can be transferred to *long-term memory*, a high-capacity system that can hold information for long periods of time (like your memory of what you did last weekend, or the capitals of states). The green arrow indicates that some of the information in long-term memory can be returned to short-term memory. The green arrow, which represents what happens when we remember something that was stored in long-term memory, is based on the idea that remembering something involves bringing it back into short-term memory.

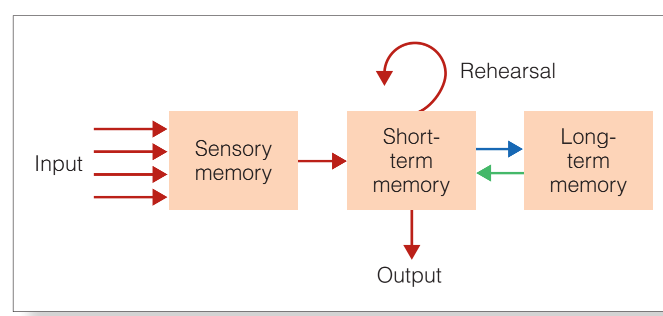


Figure 1.10 Atkinson and Shiffrin's (1968) model of memory. See text for details.

By distinguishing between different components of the memory process, this model opened the way for studying each part separately. And once researchers discovered more details about what was going on inside each of the model's boxes, they were able to subdivide these boxes into smaller units, which then could be studied in more depth. For example, Endel Tulving (1972, 1985), one of the most prominent early memory researchers, proposed that long-term memory is subdivided into three components (**Figure 1.11**). *Episodic memory* is memory for events in your life (like what you did last weekend). *Semantic memory* is memory for facts (such as the capitals of the states). *Procedural memory* is memory for physical actions (such as how to ride a bike or play the piano). Subdividing the long-term memory box into types of long-term memory added detail to the model that provided the basis for research into how each of these components operates. As you will see in every chapter of this book, the study of higher mental processes has extended to areas beyond memory. As you read this book, you will see how researchers

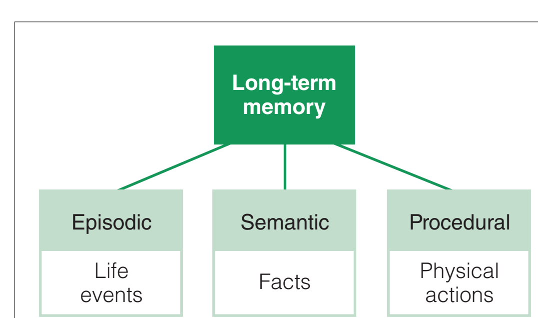


Figure 1.11 Endel Tulving (1972) divided long-term memory into three components.

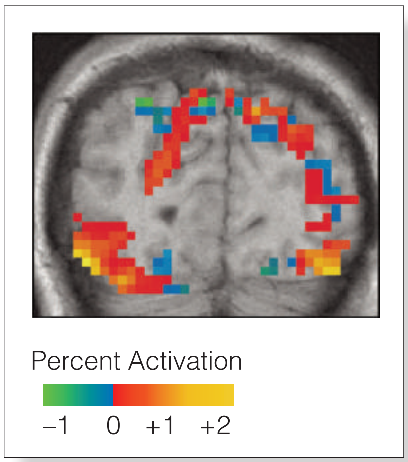
have often subdivided cognitive processes into smaller units in order to create a more detailed picture of how these processes operate.

Studying the Physiology of Cognition

While researchers were working to understand memory and other cognitive functions by doing behavioral experiments, something else was happening. Physiological research, which we will see in Chapter 2 had been making advances since the 1800s, was providing important insights into the "behind the scenes" activity in the nervous system that creates the mind.

Two physiological techniques dominated early physiological research on the mind. **Neuropsychology**, the study of the behavior of people with brain damage, had been providing insights into the functioning of different parts of the brain since the 1800s. **Electrophysiology**, measuring electrical responses of the nervous system, made it possible to listen to the activity of single neurons. Most electrophysiology research was done on animals. As we will see in Chapter 2, both neuropsychology and electrophysiology have provided important insights into the physiological basis of the mind.

But perhaps the most significant physiological advance wasn't to come until a decade after Neisser's book, when the technique of **brain imaging** was introduced. A procedure called *positron emission tomography* (PET), which was introduced in 1976, made it possible to see which areas of the human brain are activated during cognitive activity (Hoffman et al., 1976; Ter-Pogossian et al., 1975). A disadvantage of this technique was that it was expensive and involved injecting radioactive tracers into a person's bloodstream. PET was therefore replaced by *functional magnetic resonance imaging* (fMRI), which didn't involve radioactive tracers and which was capable of higher resolution (Ogawa et al., 1990). **Figure 1.12** shows the results of an fMRI experiment.



➤ **Figure 1.12** Record of brain activation determined using fMRI. Colors indicate locations of increases and decreases in brain activity. Red and yellow indicate increases in activity caused by perceiving pictures of faces. Blue and green indicate decreases. Details of this procedure will be described in Chapter 2.

(Source: Ishai, A., Ungerleider, L. G., Martin, A., & Haxby, J. V. (2000). The Representation of Objects in the Human Occipital and Temporal Cortex. *Journal of Cognitive Neuroscience, 12,* 36-51.)

The introduction of fMRI brings us back to the idea of revolutions. Thomas Kuhn's idea of paradigm shifts was based on the idea that a scientific revolution involves a shift in the way people think about a subject. This was clearly the case in the shift from the behavioral paradigm to the cognitive paradigm. But there's another kind of shift in addition to the shift in thinking: a shift in how people *do* science (Dyson, 2012; Galison, 1997). This shift, which depends on new developments in technology, is what happened with the introduction of the fMRI. *Neuroimage*, a journal devoted solely to reporting neuroimaging research, was founded in 1992 (Toga, 1992), followed by *Human Brain Mapping* in 1993 (Fox, 1993). From its starting point in the early 1990s, the number of fMRI papers published in all journals has steadily increased. In fact, it has been estimated that about 40,000 fMRI papers had been published as of 2015 (Eklund et al., 2016).

There are limitations to fMRI research, so other scanning techniques have also been developed. But there is no question that the trend started by the introduction of fMRI in 1990 caused its own revolution within cognitive psychology, which, as we will see in Chapter 2, has led to a vast increase in our knowledge of how the brain functions.

New Perspectives on Behavior

So how has cognitive psychology evolved since Neisser's 1967 "progress report"? As we have already mentioned, current cognitive psychology involves more-sophisticated flow diagrams of the mind, a consideration of higher mental processes, and also a large amount of physiological research.

Beyond developing more research on higher-level processes and physiology that we knew little about in 1967, researchers began taking research out of the laboratory. Most early research was done in laboratories, with participants sitting in one place looking at flashed stimuli, as in Donders's reaction time experiment. But it became clear that to fully understand the mind, we have to also study what happens when a person is moving through

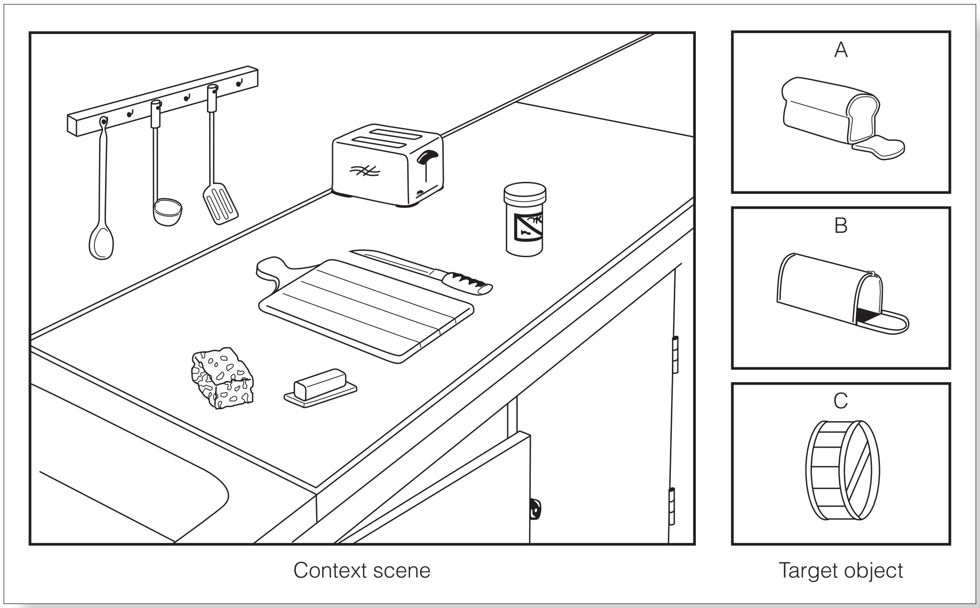


Figure 1.13 Stimuli used in Palmer's (1975) experiment. The scene at the left is presented first, and then one of the objects on the right is briefly flashed. Participants in this experiment were more accurate in identifying the bread. This indicates that their knowledge of what is usually found in kitchens influenced their performance.

the environment and acting on it. Modern cognitive psychology therefore features an increasing amount of research on cognition in "real-world" situations.

Researchers also realized that humans are not "blank slates" that just accept and store information, so they began doing experiments that demonstrated the importance of knowledge for cognition. For example, consider the picture in **Figure 1.13**, which was used by Stephen Palmer (1975) to illustrate how our knowledge about the environment can influence our perception. Palmer first presented a context scene such as the kitchen scene on the left and then briefly flashed one of the target pictures on the right. When Palmer asked observers to identify the object in the target picture, they correctly identified an object like the loaf of bread (which is appropriate to the kitchen scene) 80 percent of the time, but correctly identified the mailbox or the drum (two objects that don't fit into the scene) only 40 percent of the time. Apparently, Palmer's observers were using their knowledge of objects that are likely to be found in kitchens to help them perceive the briefly flashed loaf of bread. Of course, knowledge isn't just an interesting effect to be demonstrated in a perception experiment; it is central to most of our cognitive processing. You will see evidence for the importance of such knowledge in cognition because it appears in every chapter!

As you read this book, you will encounter a wide range of perspective and approaches. You will see how physiological research adds another dimension to our understanding of the mind; how cognitive psychology is studied in the laboratory and in real-world environments; and how the knowledge a person brings to a situation plays a central role in cognition.

SOMETHING TO CONSIDER

Learning from This Book

Congratulations! You now know how some researchers began doing cognitive psychology experiments in the 19th century, how the study of the mind was suppressed in the middle of the 20th century, how the study of the mind made a glorious comeback in the 1950s, and how present-day psychologists approach the study of the mind. One of the purposes of this chapter—to orient you to the field of cognitive psychology—has been accomplished.

Another purpose of this chapter is to help you get the most out of this book. After all, cognitive psychology is the study of the mind, and there are things that have been discovered about memory that can help you improve your study techniques so you can get as much as possible from this book and from the course you are taking. One way to appreciate how cognitive psychology can be applied to studying is to look at pages 199–202 in Chapter 7. It would make sense to skim this material now, rather than waiting. There will be some terms that you may not be familiar with, but these aren't crucial for what you want to accomplish, which is picking up some hints that will make your studying more efficient and effective. Two terms worth knowing, as you read these pages, are *encoding*—which is what is happening as you are learning the material—and *retrieval*—what is happening when you are remembering the material. The trick is to encode the material during your studying in a way that will make it easier to retrieve it later. (Also see page xxii in the preface.)

Something else that might help you learn from this book is to be aware of how it is constructed. As you read the book, you will see that often a basic idea or theory is presented and then it is supported by examples or experiments. This way of presenting information breaks the discussion of a particular topic into a series of "mini-stories." Each story begins with an idea or phenomenon and is followed by demonstrations of the phenomenon and usually evidence to support it. Often there is also a connection between one story and the next. The reason topics are presented as mini-stories is that it is easier to remember a number of facts if they are presented as part of a story than if they are presented as separate, unrelated facts. So, as you read this book, keep in mind that your main job is to understand the stories, each of which is a basic premise followed by supporting evidence. Thinking about the material in this way will make it more meaningful and therefore easier to remember.

One more thing: Just as specific topics can be described as a number of small stories that are linked together, the field of cognitive psychology as a whole consists of many themes that are related to each other, even if they appear in different chapters. Perception, attention, memory, and other cognitive processes all involve the same nervous system and therefore share many of the same properties. The principles shared by many cognitive processes are part of the larger story of cognition that will unfold as you progress through this book

TEST YOURSELF 1.1

1. What was the point of the opening story about Sam?
2. What are two ways of defining the mind?
3. Why could we say that Donders and Ebbinghaus were cognitive psychologists, even though in the 19th century there was no field called cognitive psychology? Describe Donders's experiment and the rationale behind it, and Ebbinghaus's memory experiments. What do Donders's and Ebbinghaus's experiments have in common?
4. Who founded the first laboratory of scientific psychology? Describe the method of analytic introspection that was used in this laboratory.
5. What method did William James use to study the mind?
6. Describe the rise of behaviorism, especially the influence of Watson and Skinner. How did behaviorism affect research on the mind?
7. How did Edward Tolman deviate from strict behaviorism?
8. What did Noam Chomsky say about Skinner's book *Verbal Behavior*, and what effect did that have on behaviorism?

9. What is a scientific revolution, according to Thomas Kuhn? How is the cognitive revolution similar to the revolution that occurred in physics at the beginning of the 20th century?
10. Describe the events that led to the "cognitive revolution." Be sure you understand the role of digital computers and the information-processing approach in moving psychology toward the study of the mind.
11. What was the state of cognitive psychology in 1967, according to Neisser's (1967) book?
12. What are neuropsychology, electrophysiology, and brain imaging?
13. What new perspectives on behavior emerged as cognitive psychology developed?
14. What are two suggestions for improving your ability to learn from this book?

CHAPTER SUMMARY

1. Cognitive psychology is the branch of psychology concerned with the scientific study of the mind.
2. The mind creates and controls mental capacities such as perception, attention, and memory, and creates representations of the world that enable us to function.
3. The work of Donders (simple versus choice reaction time) and Ebbinghaus (the forgetting curve for nonsense syllables) are examples of early experimental research on the mind.
4. Because the operation of the mind cannot be observed directly, its operation must be inferred from what we can measure, such as behavior or physiological responding. This is one of the basic principles of cognitive psychology.
5. The first laboratory of scientific psychology, founded by Wundt in 1879, was concerned largely with studying the mind. Structuralism was the dominant theoretical approach of this laboratory, and analytic introspection was one of the major methods used to collect data.
6. William James, in the United States, used observations of his own mind as the basis of his textbook, *Principles of Psychology*.
7. In the first decades of the 20th century, John Watson founded behaviorism, partly in reaction to structuralism and the method of analytic introspection. His procedures were based on classical conditioning. Behaviorism's central tenet was that psychology was properly studied by measuring observable behavior, and that invisible mental processes were not valid topics for the study of psychology.
8. Beginning in the 1930s and 1940s, B. F. Skinner's work on operant conditioning ensured that behaviorism would be the dominant force in psychology through the 1950s.
9. Edward Tolman called himself a behaviorist but studied cognitive processes that were out of the mainstream of behaviorism.
10. The cognitive revolution involved a paradigm shift in how scientists thought about psychology, and specifically the mind.
11. In the 1950s, a number of events occurred that led to what has been called the cognitive revolution: a decline in the influence of behaviorism and a reemergence of the study of the mind. These events included the following: (a) Chomsky's critique of Skinner's book *Verbal Behavior*; (b) the introduction of the digital computer and the idea that the mind processes information in stages, like a computer; (c) Cherry's attention experiments and Broadbent's introduction of flow diagrams to depict the processes involved in attention; and (d) interdisciplinary conferences at Dartmouth and the Massachusetts Institute of Technology.
12. Event after the shift in psychology that made studying the mind acceptable, our understanding of the mind was limited, as indicated by the contents of Neisser's (1967) book. Notable developments in cognitive psychology in the decades following Neisser's book were (1) development of more-sophisticated models; (2) research focusing on the physiological basis of cognition; (3) concern with cognition in the real world, and (4) the role of knowledge in cognition.
13. Two things that may help in learning the material in this book are to read the study hints in Chapter 7, which are based on some of the things we know about memory research, and to realize that the book is constructed like a story, with basic ideas or principles followed by supporting evidence.