SOME QUESTIONS WE WILL CONSIDER

- How is cognitive psychology relevant to everyday experience? (4)
- Are there practical applications of cognitive psychology? (4)
- How is it possible to study the inner workings of the mind when we can't really see the mind directly? (7)
- How are models used in cognitive psychology? (17)

As Raphael is walking across campus, talking to Susan on his cell phone about meeting at the student union later this afternoon, he remembers that he left the book she had lent him at home (**Figure 1.1**). "I can't believe it," he thinks, "I can see it sitting there on my desk, where I left it. I should have put it in my backpack last night when I was thinking about it."

As he finishes his call with Susan and makes a mental note to be on time for their appointment, his thoughts shift to how he is going to survive after Wednesday when his car is scheduled to go into the shop. Renting a car offers the most mobility, but is expensive. Depending on his roommate for rides is cheap, but limiting. "Maybe I'll pick up a bus schedule at the student union," he thinks, as he puts his cell phone in his pocket.

Entering his anthropology class, he remembers that an exam is coming up soon. Unfortunately, he still has a lot of reading to do, so he decides that he won't be able to go to the movies with Susan tonight as they had planned. As the lecture begins, Raphael is anticipating, with some anxiety, his meeting with Susan.

This brief slice of Raphael's life is noteworthy because it is ordinary, while at the same time so much is happening. Within a short span of time, Raphael does the following things that are related to material covered in chapters in this book:

- *Perceives* his environment—seeing people on campus and hearing Susan talking on the phone (Chapter 3: Perception)
- *Pays attention* to one thing after another—the person approaching on his left, what Susan is saying, how much time he has to get to his class (Chapter 4: Attention)
- *Remembers* something from the past—that he had told Susan he was going to return her book today (Chapters 5–8: Memory)
- *Distinguishes items in a category,* when he thinks about different possible forms of transportation—rental car, roommate's car, bus (Chapter 9: Knowledge)
- *Visualizes* the book on his desk the night before (Chapter 10: Visual Imagery)
- *Understands and produces language* as he talks to Susan (Chapter 11: Language)
- Works to *solve a problem,* as he thinks about how to get places while his car is in the shop (Chapter 12: Problem Solving)
- *Makes a decision,* when he decides to postpone going to the movies with Susan so he can study (Chapter 13: Judgment, Decisions, and Reasoning)

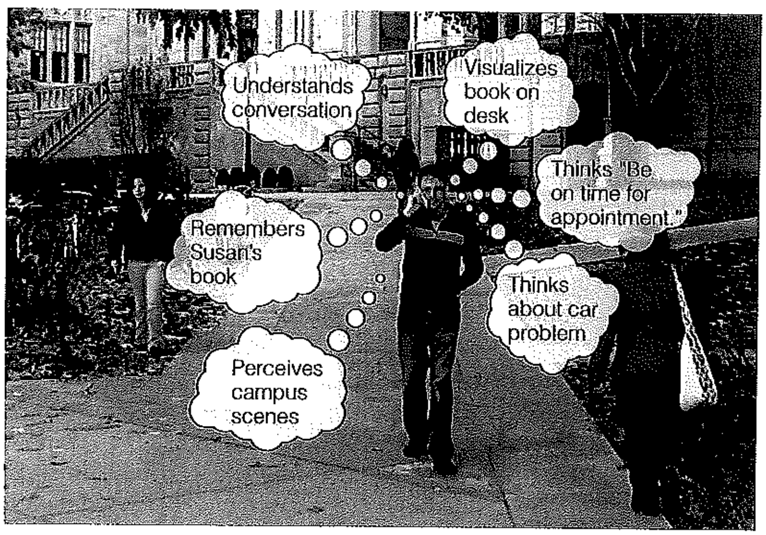


Figure 1.1 What's happening in Raphael's mind as he walks across campus? Each of the thought bubbles corresponds to something in the story in the text.

The things Raphael is doing not only are covered in this book but also have something very important in common: They all involve the mind. Cognitive psychology is *the branch of psychology concerned with the scientific study of the mind.* As you read the story told in this book, about the quest to understand the mind, you will learn what the mind is, how it has been studied, and what researchers have discovered about how the mind works. In this chapter we will first describe the mind in more detail, then consider some of the history behind the field of cognitive psychology, and finally begin considering how modern cognitive psychologists have gone about studying the mind.

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 titles of the chapters in this book.

Another definition, which focuses on how the mind operates, is: *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, that are what the mind does. 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.

What exactly are the properties of the mind? What are its characteristics? How does it operate? Saying that the mind creates cognition and is important for functioning and survival tells us *what the mind does*, but not *how it achieves what it does*. The question of how the mind achieves what it does is what cognitive psychology is about. 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

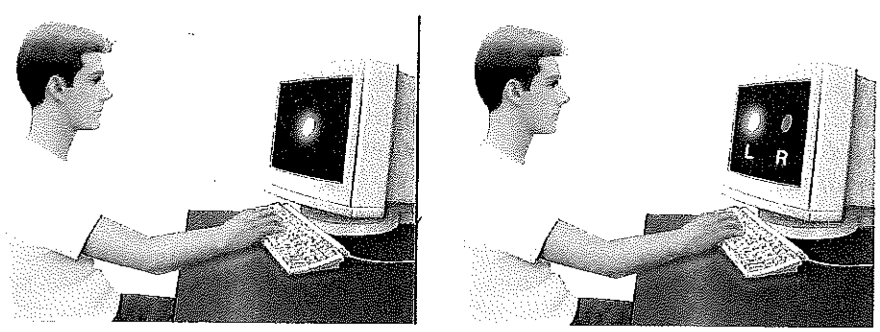
In the 1800s, ideas about the mind were dominated by the belief that it is not possible to study the mind. One reason given was that it is not possible for the mind to study itself, but there were other reasons as well, including the idea that the properties of the mind simply cannot be measured. Nonetheless, 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 subjects to push a button as rapidly as possible when they saw a light go on (Figure 1.2a). He measured choice reaction time by using two lights and asking his subjects 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 1.2b).

The steps that occur in the simple reaction time task are shown in Figure 1.3a. Presenting the stimulus (the light) 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.

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 subjects to decide whether the left or right light was illuminated and then which button to push. The diagram for this task, in Figure 1.3b, adds deciding which light was illuminated and which button to push to the mental response. 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*



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

Figure 1.2 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 subject pushes the J key when the light goes on. In the choice reaction time task, the subject 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. © Cengage Learning from behavior. We can see why this is so by noting the dashed lines in Figure 1.3. These lines indicate that when Donders measured reaction time, he was measuring the relationship between presentation of the stimulus and the subject'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.

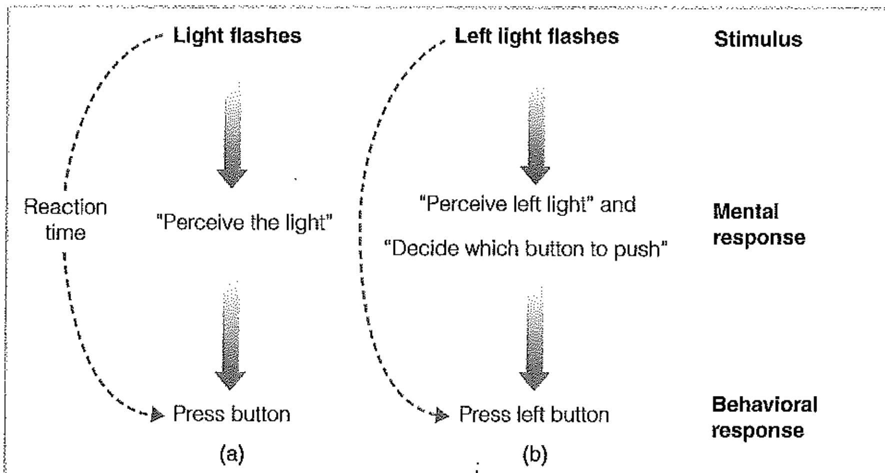


Figure 1.3 Sequence of events between presentation of the stimulus and the behavioral response in Donders's experiments: (a) simple reaction time task and (b) choice reaction time task. The dashed line indicates that Donders measured reaction time—the time between presentation of the light and the participant's 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 subjects described their experiences and thought processes in response to stimuli. Analytic introspection required extensive training because the subjects' 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 subjects 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 subject, 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

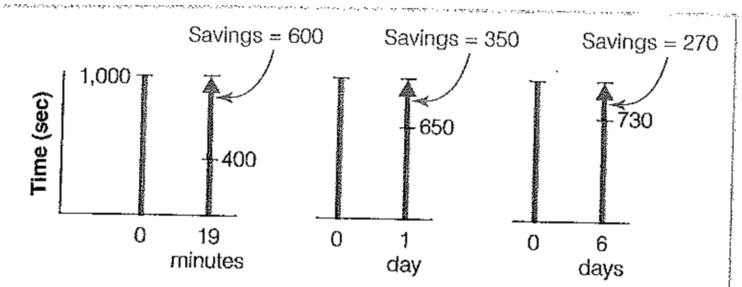


Figure 1.4 Calculating the savings score in Ebbinghaus's experiment. In this example, it took 1,000 seconds to learn the list of nonsense syllables for the first time. This is indicated by the lines at 0. The time needed to relearn the list at delays of (a) 19 minutes, (b) 1 day, and (c) 6 days are indicated by the line to the right of the 0 line. The red line indicates the savings score for each delay. Notice that savings decrease for longer delays. This decrease in savings provides a measure of forgetting.

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.

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 1.4, 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 1.5, 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*.

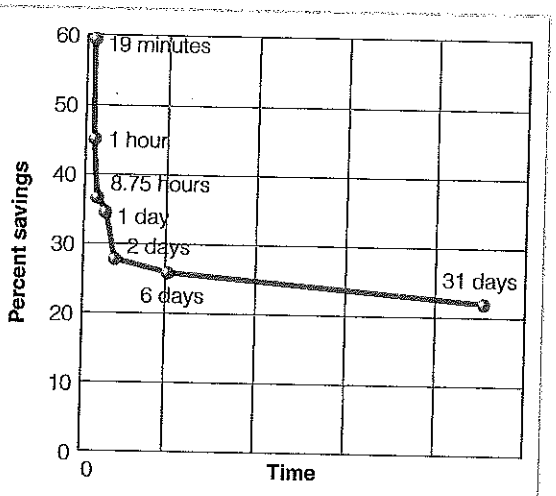


Figure 1.5 Ebbinghaus's savings curve. Ebbinghaus considered the percent savings to be a measure of the amount remembered, so he plotted this versus the time between initial learning and testing. The decrease in savings (remembering) with increasing delays indicates that forgetting occurs rapidly over the first 2 days and then occurs more slowly after that. *(Source: Based on H. Ebbinghaus,* Memory: A contribution to experimental psychology, *H. A. Ruger & C. E. Bussenius, Trans., New York: Teachers College, Columbia University, 1885/1913.)*

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.

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 vs. 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?"

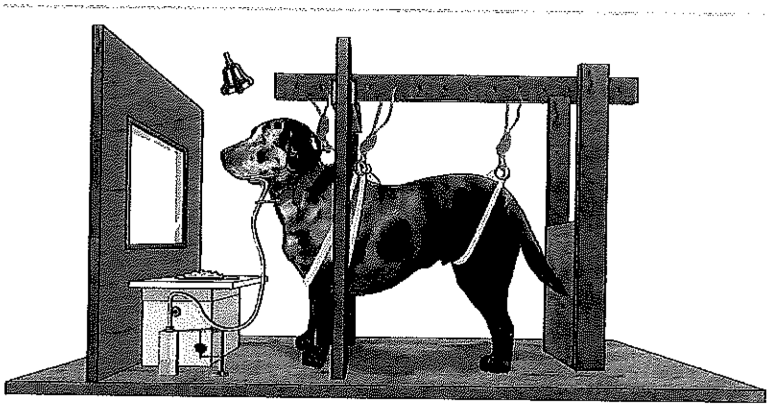


Figure 1.6 In Pavlov's famous experiment, he paired ringing a bell with presentation of food. Initially, presentation of the food caused the dog to salivate, but after a number of pairings of bell and food, the bell alone caused salivation. This principle of learning by pairing, which came to be called *classical conditioning*, was the basis of Watson's "Little Albert" experiment.

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 1.6**), 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).

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 1.7** 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 eventually led to the rebirth of the study of the mind.

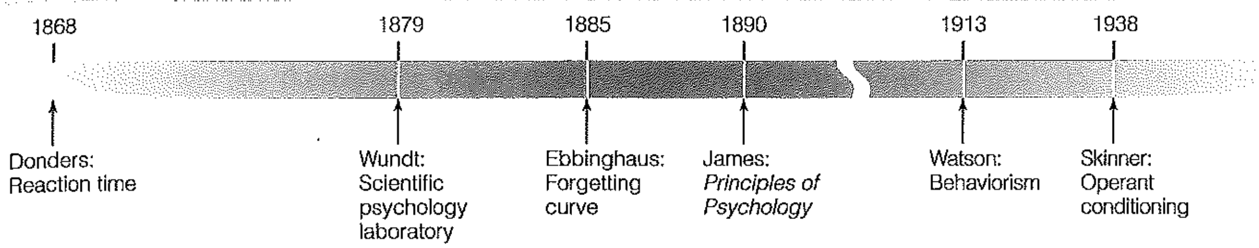


Figure 1.7 Time line showing early experiments studying the mind in the 1800s and the rise of behaviorism in the 1900s.

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.

In one of his experiments, Tolman (1938) placed a rat in a maze like the one in **Figure 1.8**. Initially, the rat explored the maze, running up and down each of the alleys (**Figure 1.8a**). After this initial period of exploration, the rat was placed at A and food was placed at 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 1.8b**). 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 C, something interesting happened. The rat turned *left* at the intersection to reach the food at B (**Figure 1.8c**). 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 it should 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.

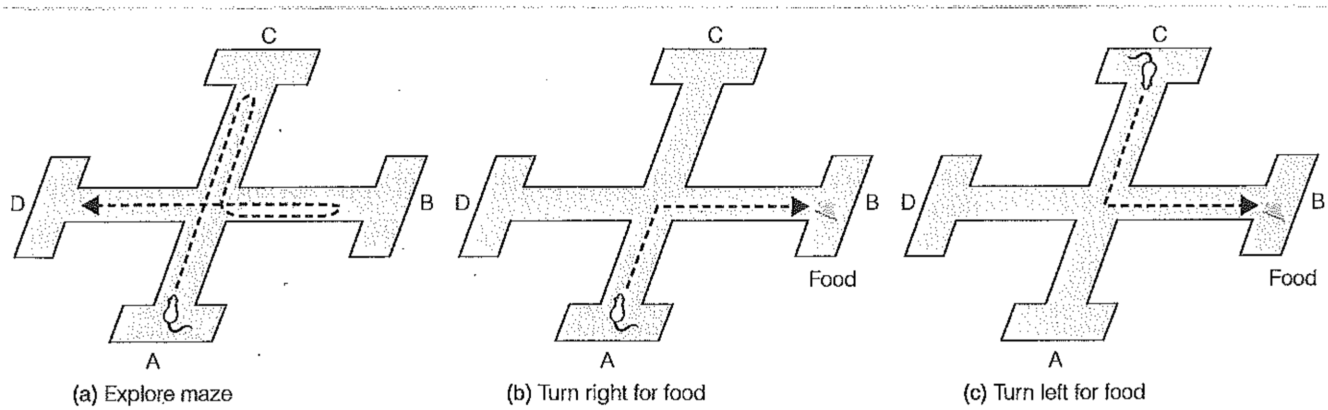


Figure 1.8 Maze used by Tolman. (a) The rat initially explores the maze. (b) The rat learns to turn right to obtain food at B when it starts at A. (c) When placed at C, the rat turns left to reach the food at B. In this experiment, precautions are taken to prevent the rat from knowing where the food is based on cues such as smell.

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 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.

Saying that psychologists should go beyond just looking at behavior and look at how the mind operates is one thing. But in order to look beyond behavior, psychologists needed to develop new ways of conceptualizing the mind. Luckily, just as psychologists were questioning behaviorism, a new technology was emerging 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 1.9a**. 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 subjects 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 subject 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 ..."

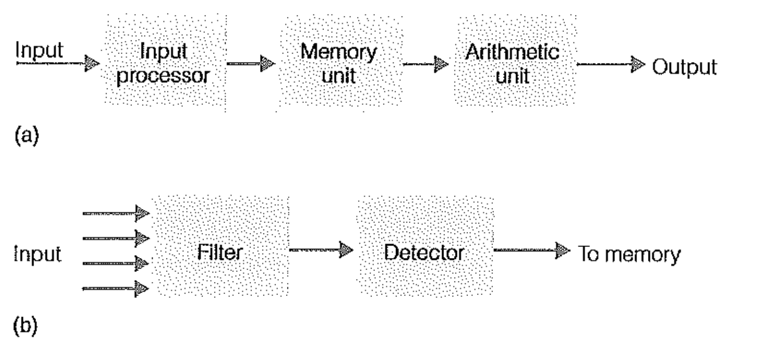


Figure 1.9 (a) Flow diagram for an early computer; (b) flow diagram for Broadbent's filter model of attention. This diagram shows many messages entering a "filter," which selects the message to which the person is attending for further processing by a detector and then storage in memory. We will describe this diagram more fully in Chapter 4. © Cengage Learning

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 1.9b**). This diagram represents what 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.

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 the human's ability to process information—that the information processing 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 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 1.10** shows a time line of some of the events that led to the establishment of the field of cognitive psychology.

LOOKING AHEAD

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

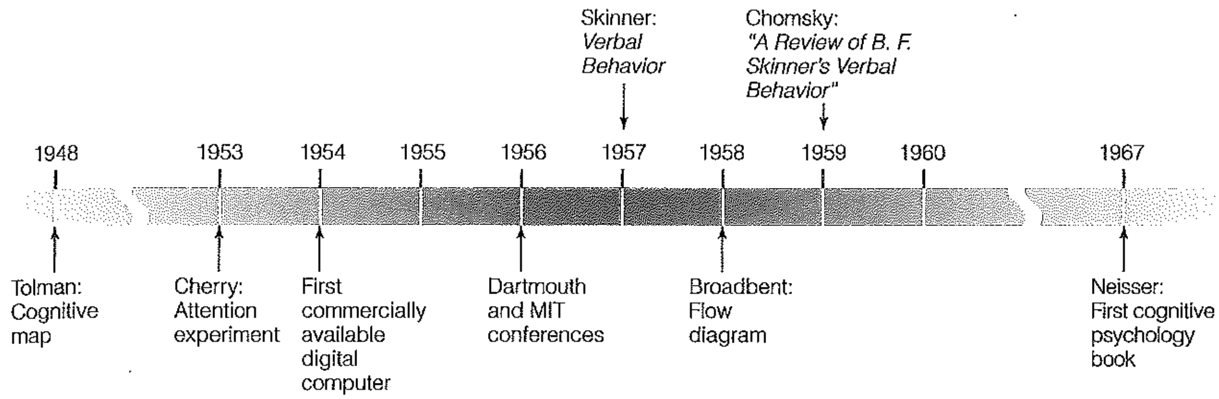


Figure 1.10 Time line showing events associated with the decline of the influence of behaviorism (above the line) and events that led to the development of the information-processing approach to cognitive psychology (below the line).

the information-processing approach to studying the mind, has become one of the dominant approaches in psychology.

We have come a long way since Donders measured the relationship between reaction time and making a decision (should I press the left button or the right button?). But modern cognitive psychology experiments still measure relationships. For example, we will see that it is easier to remember the first and last words than those in the middle of a list of 20 words we have just heard (Chapter 5: Memory); that we respond faster to words that appear more frequently in our language (like *house*) than to words that appear less frequently (like *hike*) (Chapter 11: Language); and that people often judge events they have heard about (like tornados) as more likely to cause death than events they haven't heard much about (like asthma), even though the opposite might be true (asthma is 20 times more likely to cause death than tornados) (Chapter 13: Judgment, Decisions, and Reasoning).

The goal of all of the experiments that measure these relationships is to use behavior to reveal how the mind operates. But the goal of modern cognitive psychology research extends beyond measuring single relationships, because the ultimate goal is to understand the mind, and the mind is a complex system.

Modern Research in Cognitive Psychology

How do cognitive psychologists think about the complexity of the mind? How does this influence the questions they ask and the experiments they carry out? The answers to these questions may be different for different researchers and different types of problems, but we will consider two aspects of research that apply to cognitive psychology in general: (1) how research progresses from one question to another; and(2) the role of models in cognitive psychology.

FOLLOWING A TRAIL: HOW RESEARCH PROGRESSES FROM ONE QUESTION TO ANOTHER

Research in cognitive psychology, like research in science in general, begins with what is known about a problem. From that starting point, researchers ask questions, design experiments, and obtain and interpret results. These findings then become the basis for new questions, experiments, and results. We can thus think of the process of research in terms of following a trail in which one thing leads to another. As with many trails, there are places where it is necessary to choose one path or another. In terms of research, the pathway taken is determined by the questions that are asked. The biggest challenge of research is, therefore, not doing the experiments, but picking the right questions.

To illustrate the idea of research as following a trail, we will describe research by Sian Beilock (2010) on the problem of "choking under pressure," where *choking* is performing more poorly than expected given a person's skill level when the person feels pressure to perform at a high level. We pick this research because the topic of choking is relevant to many people's experience, and because the experiments we are going to describe provide a good example of following a trail in which one question leads to another.

Choking is observed in many different contexts. A golfer flubbing an easy putt that would have clinched a championship and a basketball player "going cold" and missing 10 shots in a row in a crucial game are examples of choking in sports. Choking can also occur in an academic setting. Josh studies hard for an important exam and feels he knows the material, but he becomes nervous in the testing situation and does poorly.

In one of Beilock's early papers, written when she was a graduate student in Thomas Carr's laboratory at Michigan State University, she begins by stating that "the phenomenon of choking under pressure remains to be explained" (Beilock & Carr, 2001). The beginning of the research trail, then, was a phenomenon (choking) that needed an explanation. Another starting point was the proposal of a type of memory called *working memory*, which is involved in holding information in memory as it is being manipulated, as occurs when doing a math problem in our head (Baddeley & Hitch, 1974).

To look for a link between working memory and choking, Beilock and Carr (2004) did an experiment in which they presented subjects with math problems and asked them to indicate whether the result had a remainder. For example, for the problem below, answer "yes" if there is a remainder, "no" if there isn't.

(32 – 8) divided by 4 = ?

Think about how you solved the problem (we'll come back to this later), then try this one:

(32 – 6) divided by 4 = ?

The answers are "no" for the first problem and "yes" for the second.

When Beilock presented problems such as these to subjects under low-pressure conditions ("Here's a problem") and high-pressure conditions ("You will be videotaped and need to do well to receive a cash payment"), she found that performance decreased (choking occurred) for problems that were more difficult and so depended more on working memory. The reason for this finding, Beilock hypothesized, was that pressure caused subjects to worry, and this worry used up some of their working memory capacity.

Let's stop for a moment to appreciate what this conclusion means. This research has gone beyond simply describing a phenomenon ("People choke under pressure") or showing when it occurs ("Choking is more likely for hard tasks") to hypothesizing something about *what is going on in the mind* ("Working memory is being disrupted"). Does this sound familiar? This is the Donders technique of measuring behavior and then inferring what is happening in the mind.

But remember that we are following a trail, and another question is required in order to continue. Beilock posed that question in her next paper (Beilock & Carr, 2005) by stating that in order to understand the causal mechanism responsible for choking, "one must identify the characteristics of individuals most likely to fail." Following this idea, Beilock again built on previous research. Twenty-five years earlier, Meredyth Daneman and Patricia Carpenter (1980) had developed a test to measure working memory capacity and found that, based on this test, they could divide their subjects into two groups: low working memory (LWM) subjects and high working memory (HWM) subjects.

With this division of subjects into LWM and HWM in mind, Beilock used the experimental design shown in **Figure 1.11**, in which LWM and HWM subjects did the math problems under either low-pressure or high-pressure conditions. Based on what you now know, which subjects do you think were more likely to choke under pressure? It makes sense to think that the LWM subjects would be more likely to choke, because worrying could use up their already limited working memory capacity.

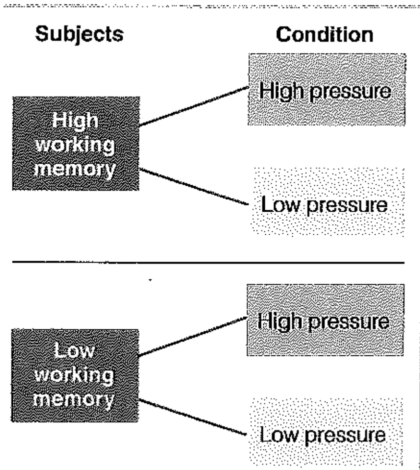


Figure 1.11 Experimental design for Beilock and Carr's (2005) experiment. See text for details.

But remember that research builds upon previous results, and Michael Kane and Randall Engle (2000) had recently published a paper in which they presented a verbal task to LWM and HWM subjects under two conditions: low load (the verbal task was presented alone) and high load (subjects did another task while they were doing the verbal task). In the low load condition, HWM subjects performed better than the LWM subjects, but in the high load condition, the performance of both groups was the same. Thus, the advantage of the HWM subjects vanished under high load conditions.

Kane and Engle's result, and the reasons for it (which we won't go into here), led Beilock to expect that HWM subjects would be more likely to choke under high pressure, and **Figure 1.12** shows that this is exactly what happened. HWM subjects did better than LWM subjects under low-pressure conditions, but the performance of HWM subjects decreased in the high-pressure situation. In other words, subjects with the best working memory reserves were more likely to choke.

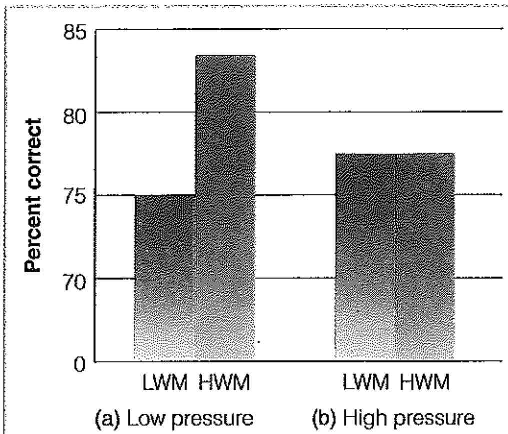


Figure 1.12 Results of the Beilock and Carr (2005) experiment show mathematics problem-solving performance for low working memory (LWM) and high working memory (HWM) subjects under (a) low-pressure and (b) high-pressure conditions. HWM subjects performed better under low-pressure conditions, but lost their advantage under high-pressure conditions. *(Source: Based on S. L. Beilock & T. H. Carr, When high-powered people fail,* Psychological Science, 16, 101–105, 2005.)

In research, one result leads to another question, and the next question was why the HWM subjects were more susceptible to choking. Perhaps, Beilock thought, the answer could be found by considering the strategy that LWM and HWM subjects used to solve the math problems.

How is it possible to determine the strategy a person is using to solve a problem? One way is to ask them! When Beilock and Marci DeCaro (2007) asked their subjects to solve problems and then describe how they had solved them, they found that in low-pressure situations, the HWM subjects were more likely to arrive at their answer by doing the calculation. Thus, in our first example, on page 16, they would subtract 8 from 32 and divide the result by 4. This method always results in the correct answer but places a heavy load on working memory. In contrast, the LWM subjects were more likely to use a "short cut" that states that if all of the numbers are even, the answer is "no." This strategy works for many problems (like the first one), but not for all (like the second one). This short-cut strategy places a low load on working memory, but doesn't always result in the correct answer.

The strategy used by the HWM subjects in the low-pressure condition is clearly better in terms of accuracy, and that's why they score higher in the low-pressure condition. But increasing the pressure increased the likelihood that HWM subjects would shift to the short-cut strategy. When they did this, their performance dropped to the level of the LWM subjects. Meanwhile, the LWM subjects continued using the short-cut strategy, which, because it didn't use much working memory, wasn't affected by the pressure.

There are, of course, further questions that could be asked about choking. One of them is "How can choking be prevented?" which Beilock (2010) investigated in further experiments. Thus, understanding cognitive mechanisms underlying behavior is not just of academic interest. Practical applications such as ways to help people cope with pressure, or how to study more effectively (which we will discuss in Chapter 7), often follow from basic research on cognitive mechanisms.

From this example of starting with a phenomenon and then following a trail created by asking questions, observing experimental results, asking further questions, and so on, we can appreciate the complexities faced by researchers who are studying cognitive processes. One way cognitive psychologists have dealt with this complexity is to create models that represent structures and processes involved in cognition.

THE ROLE OF MODELS IN COGNITIVE PSYCHOLOGY

Models are representations of structures or processes that help us visualize or explain the structure or process. We will consider two kinds of models: *structural models*, which represent structures in the brain that are involved in specific functions; and *process models*, which illustrate how a process operates.

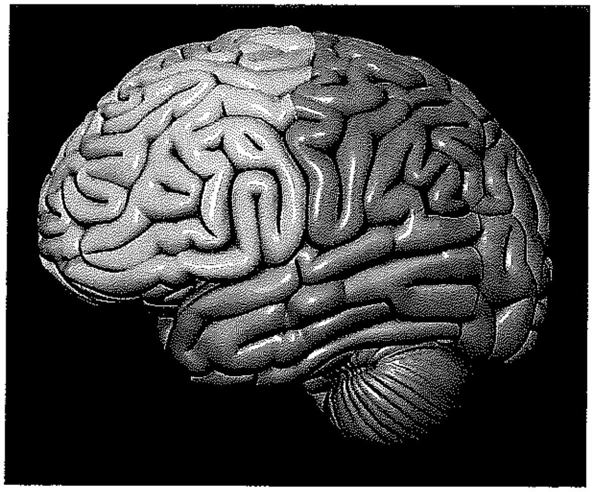

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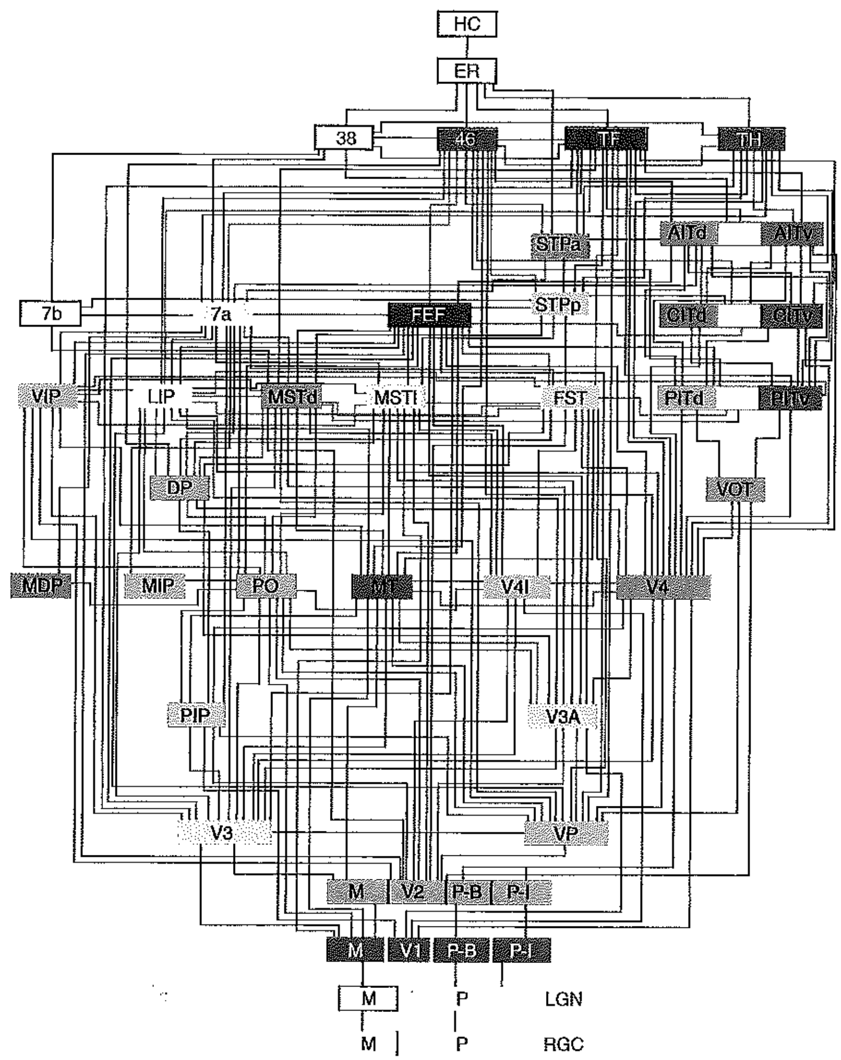
Figure 1.13 A plastic model of the brain can be used to illustrate the locations of different brain structures.

STRUCTURAL MODELS Structural models are representations of a physical structure. A model can mimic the appearance of an object, as a model car or airplane represents the appearance of a real car or airplane. Similarly, plastic models such as the one in Figure 1.13 have been used to illustrate the locations of different structures of the brain. Structures can also be represented by diagrams that don't resemble the structure but that instead indicate how different areas of the brain are connected. For example, Figure 1.14 indicates the complexities of the connections between structures in the visual system.

One purpose of models is to simplify. We can appreciate this purpose by considering how we might build a model of the brain. The plastic model in Figure 1.13 can be taken apart to reveal different structures. Of course, this model isn't anything like a real brain, because besides being made of plastic, it doesn't show what is happening inside each structure and how the structures are connected to each other. We would have to increase the amount of detail in our model to represent this. In fact, if we really wanted our model to be like the brain, we would represent the individual cells, called neurons, that make up the brain (which we will describe in Chapter 2) and how they are connected. But this would be no easy task, because there are

Figure 1.14 A model of the visual system. Each box represents a structure. Lines represent connections between structures. *(Source: D. J. Felleman & D. C. Van Essen, Distributed hierarchical processing in the primate cerebral cortex,* Cerebral Cortex, 1, *1–47, 1991).*



more than 100 billion neurons in the human brain and about 10 trillion connections between them (Horstman, 2012).

Our hypothetical exercise in model building has gotten out of hand, because representing every neuron and every connection takes us far beyond our present knowledge of the brain. Models are not identical replicas of the real thing. They are simplifications that don't contain as much detail, but do contain important information about the structures being represented. Even the complex model of the visual system in **Figure 1.14** is simplified, because each box represents a complex structure. Nonetheless, this model helps us visualize the layout of a system and how different components are connected and might interact. The simplification that is a characteristic of most models is actually an advantage, because it makes it easier to study and understand the system.

It is important to note that most structural models are designed to represent the structures involved in specific functions. Thus, all of the structures in **Figure 1.14** are involved in vision. In Chapter 3, we will describe a model of the system involved in identifying objects. Or consider **Figure 1.15**, which shows a model depicting a group of structures, called the *pain matrix,* that are involved in our perception of pain. This model identifies structures that create different components of the pain experience, which when activated communicate with each other to create the overall experience of pain.

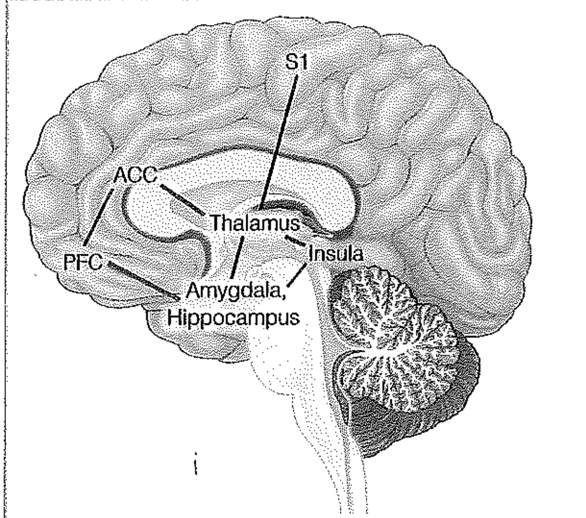


Figure 1.15 Pain matrix, showing some of the structures that are involved in experiencing pain, and their connections.

PROCESS MODELS **Process models** represent the processes that are involved in cognitive mechanisms, with boxes usually representing specific processes and arrows indicating connections between processes. Broadbent's filter model of attention is an example of a process model. In this model, the box representing the "filter" represents the process that separates the attended message from other messages. This process is not necessarily located in one particular place in the brain, so the boxes do not necessarily represent specific structures; rather, they indicate a process that could be carried out by a number of different structures working together.

Figure 1.16 shows a process model that represents the operation of memory. This model of memory, which we will describe in Chapter 5, was proposed in the 1960s and guided memory research for many years. *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 names of recent U.S. presidents). 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.

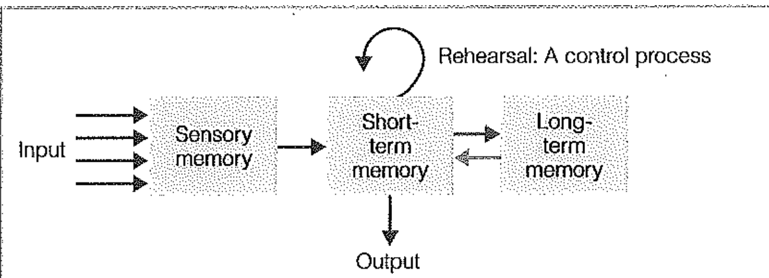


Figure 1.16 An early model of memory. *(Source: Based on R. C. Atkinson & R. M. Shiffrin, Human memory: A proposed system and its control processes, in K. W. Spence & J. T. Spence, Eds.,* The psychology of learning and motivation, *Vol. 2, pp. 89–195, New York: Academic Press, 1968.)*

Process models like this one make complicated systems easier to understand and also provide a starting point for research. For example, research on the long-term component of the memory model in **Figure 1.16** has shown that there are a number of different types of long-term memory, illustrated in **Figure 1.17** (Tulving, 1972, 1985). *Episodic memory* is memory for events in your life (like what you did last weekend). *Semantic memory* is memory for facts (such as the names of recent

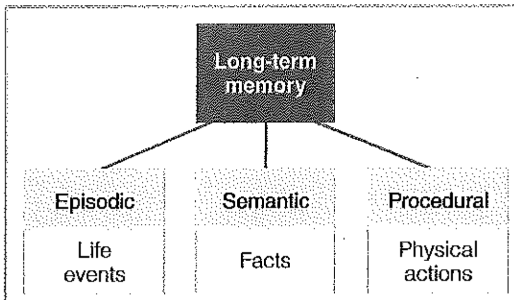


Figure 1.17 A diagram showing three components of long-term memory. *(Source: Based on E. Tulving, How many memory systems are there?* American Psychologist, 40, *385–398, 1985.)*

U.S. presidents). *Procedural memory* is memory for physical actions (such as how to ride a bike or play the piano). Realizing that the long-term memory box can be subdivided 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 we will see in Chapters 6, 7, and 8, there is evidence that these components are served by different areas of the brain, that their operation is based on different mechanisms, and that they interact with each other to create our total experience of memory. Thus, models simplify complex systems but often become more detailed as researchers study the different components of a model.

We have emphasized behavior in this chapter, because behavior is what cognitive psychologists are trying to explain. But in addition to measuring behavior, cognitive psychologists also measure physiological processes that underlie that behavior. For example, in addition to considering how memory operates behaviorally, cognitive psychologists are also interested in how memory operates in the brain. In fact, for every behavioral question, there is a physiological question, because the brain is the "machinery" responsible for creating the behavior. In Chapter 2: Cognitive Neuroscience, we will introduce principles of brain operation and methods used to uncover the physiological mechanisms of 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 why present-day psychologists create models 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 202–203 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 xxvi 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 are two ways of defining the mind?
2. 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?
3. Who founded the first laboratory of scientific psychology? Describe the method of analytic introspection that was used in this laboratory.
4. What method did William James use to study the mind?
5. Describe the rise of behaviorism, especially the influence of Watson and Skinner. How did behaviorism affect research on the mind?
6. Describe the events that helped lead to the decline in importance of behaviorism in psychology and the events that led to the "cognitive revolution." Be sure you understand what the information-processing approach is.
7. Describe the research on choking under pressure. How does this example illustrate how research progresses from one question to another, and how behavior is used to infer what is going on in the mind?
8. Why are models important in cognitive psychology? What are structural models? Process models? Do the boxes in process models correspond to structures in the brain?
9. 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 vs. 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 assured that behaviorism would be the dominant force in psychology through the 1950s.
9. 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.

10. The phenomenon of choking under pressure, as studied by Sian Beilock, illustrates how research progresses from one question to the next, and how the results of behavioral experiments can be used to infer what is happening in the mind.

11. Models play an essential role in cognitive psychology by representing structures or processes. Structural models represent structures in the brain and how they are connected. Process models illustrate how a process operates. Models make complicated systems easier to understand and often provide a starting point for research.

12. 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.

THINK ABOUT IT

1. What do you think the "hot topics" of cognitive psychology are, based on what you have seen or heard in the media? Hint: Look for stories such as the following: "Scientists Race to Find Memory Loss Cure"; "Defendant Says He Can't Remember What Happened."

2. The idea that we have something called "the mind" that is responsible for our thoughts and behavior is reflected in the many ways that the word *mind* can be used. A few examples of the use of *mind* in everyday language were cited at the beginning of the chapter. See how many more examples you can think of that illustrate different uses of the word *mind*, and decide how relevant each is to what you will be studying in cognitive psychology (as indicated by the table of contents of this book).

3. The idea that the operation of the mind can be described as occurring in a number of stages was the central principle of the information-processing approach, which was one of the outcomes of the cognitive revolution that began in the 1950s. How can Donders's reaction time experiment from the 1800s be conceptualized in terms of the information-processing approach?

4. Donders compared the results of his simple and choice reaction time experiments to infer how long it took, when given a choice, to make the decision as to which button to push. But what about other kinds of decisions? Design an experiment to determine the time it takes to make a more complex decision. Then relate this experiment to the diagram in Figure 1.3.

KEY TERMS

Analytic introspection, 7
Artificial intelligence, 13
Behaviorism, 9
Choice reaction time, 6
Classical conditioning, 10
Cognition, 5
Cognitive map, 11
Cognitive psychology, 4
Cognitive revolution, 12
Information-processing approach, 12
Logic theorist, 14
Mind, 4
Operant conditioning, 10
Process model, 19
Reaction time, 6
Savings, 8
Savings curve, 8
Simple reaction time, 6
Structuralism, 7
Structural model, 18

COGLAB EXPERIMENT

Number in parentheses refers to the experiment number in CogLab.

Simple Detection (2)