The Science of the Mind
Almost everything you do, and everything you feel or say, depends on your *cognition*—what you know, what you remember, and what you think. As a result, the book you’re now reading—a textbook on cognition—describes the foundation for virtually every aspect of who you are.

As illustrations of this theme, in a few pages we’ll consider the way in which your ability to cope with grief depends on how your memory functions. We’ll also discuss the role that memory plays in shaping your self-image—and, hence, your self-esteem. As a more mundane example, we’ll also discuss a case in which your understanding of a simple story depends on the background knowledge that you supply. Examples like these make it clear that cognition matters in an extraordinary range of circumstances, and it is on this basis that our focus in this book is, in a real sense, on the intellectual foundation of almost every aspect of human experience.

**The Scope of Cognitive Psychology**

When the field of cognitive psychology was first launched, it was broadly focused on the *scientific study of knowledge*, and this focus led immediately to a series of questions: How is knowledge acquired? How is knowledge retained so that it’s available when needed? How is knowledge used—whether as a basis for making decisions or as a means of solving problems?

These are great questions, and it’s easy to see that answering them might be quite useful. For example, imagine that you’re studying for next Wednesday’s exam, but for some reason the material just won’t “stick” in your memory. You find yourself wishing, therefore, for a better strategy to use in studying and memorizing. What would that strategy be? Is it possible to have a “better memory”?

As a different case, let’s say that while you’re studying, your friend is moving around in the room, and you find this to be quite distracting. Why can’t you just shut out your friend’s motion? Why don’t you have better control over your attention and your ability to concentrate?

Here’s one more example: You pick up the morning newspaper, and you’re horrified to learn how many people have decided to vote for candidate X. How do people decide whom to vote for? For that matter, how do people decide what college to attend, or which car to buy, or even what to have for dinner? And how can we help people make *better* decisions—so that, for example, they choose healthier foods, or vote for the candidate who (in your view) is obviously preferable?
preview of chapter themes

• The chapter begins with a description of the scope of cognitive psychology. The domain of this field includes activities that are obviously "intellectual" (such as remembering, or attending, or making judgments) but also a much broader range of activities that depend on these intellectual achievements.
• What form should a "science of the mind" take? We discuss the difficulties in trying to study the mind by means of direct observation. But we also explore why we must study the mental world if we are to understand behavior; the reason, in brief, is that our behavior depends, in crucial ways, on how we perceive and understand the world around us.
• Combining these themes, we are led to the view that we must study the mental world indirectly, but as we will see, the (inferential) method for doing this is the same method used by most sciences.
• Finally, we consider examples of research in cognitive psychology to illustrate the types of data that psychologists consider and the logic they use in testing their theories.

Before we’re through, we’ll consider evidence pertinent to all of these questions. Let’s note, though, that in these examples, things aren’t going as you might have wished: You remember less than you want to; you’re unable to ignore a distraction; the voters make a choice you don’t like. But what about the other side of the picture? What about the remarkable intellectual feats that humans achieve—brilliant deductions or creative solutions to complex problems? In this text, we’ll also discuss these cases and explore how it is that people accomplish the great things they do.

TRYING TO FOCUS

Often, you want to focus your attention on just one thing, and you want to shut out the other sights and sounds that are making it hard for you to concentrate. What steps should you take to promote this focus and to avoid distraction?
The Broad Role for Memory

Clearly there is an important set of issues in play here, but even so, the various questions just catalogued risk a misunderstanding, because they make it sound like cognitive psychology is concerned only with our functioning as intellectuals—our ability to remember, or to pay attention, or to think through options when making a choice. As we said at the start, though, the relevance of cognitive psychology is far broader—thanks to the fact that a huge range of our actions, thoughts, and feelings depend on knowledge. As one illustration of this point, let’s look at the study of memory and ask: When we investigate how memory functions, what exactly is it that we’re investigating? Or, to turn this around, what aspects of your life depend on memory?

You obviously rely on memory when you’re taking an exam—memory for what you have learned during the term. Likewise, you rely on memory when you’re at the supermarket and trying to remember the cheesecake recipe so that you can buy the right ingredients. You also rely on memory when you’re reminiscing about childhood. But what else draws on memory?

Consider this simple story (adapted from Charniak, 1972):

Betsy wanted to bring Jacob a present. She shook her piggy bank. It made no sound. She went to look for her mother.

This four-sentence tale is easy to understand, but only because you provided some important bits of background yourself. For example, you weren’t at all puzzled about why Betsy was interested in her piggy bank; you weren’t puzzled, specifically, about why the story’s first sentence led naturally to the second. This is because you already knew (a) that the things one gives as presents are often things bought for the occasion (rather than things already owned), (b) that buying things requires money, and (c) that money is stored in piggy banks. Without these facts, you would have been bewildered as to why a desire to give a gift would lead someone to her piggy bank. (Surely you did not think she intended to give the piggy bank itself as the present!) Likewise, you immediately understood why Betsy shook her piggy bank. You didn’t suppose that she was shaking it in frustration or trying to find out if it would make a good percussion instrument. Instead, you understood that she was trying to determine its contents. But you knew this fact only because you already knew (d) that children don’t keep track of how much money is in their bank, and (e) that one cannot simply look into the bank to learn its contents. Without these facts, Betsy’s shaking of the bank would make no sense. Similarly, you understood what it meant that the bank made no sound. That’s because you know (f) that it’s usually coins (not bills) that are kept in piggy banks, and (g) that coins make noise when they are shaken. If you didn’t know these facts, you might have interpreted the bank’s silence, when it was shaken, as good news, indicating perhaps that the bank was jammed full of $20 bills—an inference that would have led you to a very different expectation for how the story would unfold from there.
CELEBRATING HUMAN ACHIEVEMENTS

Many of the text's examples involve failures or limitations in our cognition. But we also need to explain our species' incredible intellectual achievements—the complex problems we've solved or the extraordinary devices we've invented.

Of course, there's nothing special about the “Betsy and Jacob” story, and it seems likely that we'd uncover a similar reliance on background knowledge if we explored how you understand some other narrative, or how you follow a conversation, or comprehend a TV show. Our suggestion, in other words, is that many (and perhaps all) of your encounters with the world depend on your supplementing your experience with knowledge that you bring to the situation. And perhaps this has to be true. After all, if you didn't supply the relevant bits of background, then anyone telling the “Betsy and Jacob” story would need to spell out all the connections and all the assumptions. That is, the story would have to include all the facts that, with memory, are supplied by you. As a result, the story would have to be many times longer, and the telling of it much slower. The same would be true for every story you hear, every conversation you participate in. Memory is thus crucial for each of these activities.

Amnesia and Memory Loss

Here is a different sort of example: In Chapter 7, we will consider various cases of clinical amnesia—cases in which someone, because of brain damage, has lost the ability to remember certain materials. These cases are fascinating at many levels, including the fact that they provide us with key insights into what memory is for: Without memory, what is disrupted?

H.M. was in his mid-20's when he had brain surgery intended to control his severe epilepsy. He survived for more than 50 years after the operation, and for all of those years, he had little trouble remembering events prior to the surgery. However, H.M. seemed completely unable to recall any event that occurred after his operation. If asked who the president is, or about recent events, he reported facts and events that were current at the time of the surgery. If asked questions about last week, or even an hour ago, he recalled nothing.

This memory loss had massive consequences for H.M.'s life, and some of the consequences are perhaps surprising. For example, H.M. had an uncle he was very fond of, and he occasionally asked his hospital visitors how his uncle was doing. Unfortunately, the uncle died sometime after H.M.'s surgery, and H.M. was told this sad news. The information came as a horrible shock, but because of his amnesia, he soon forgot about it.

Sometime later, though, because he'd forgotten about his uncle's death, H.M. again asked how his uncle was doing, and was again told of the death. However, with no memory of having heard this news before, he was once more hearing it “for the first time,” with the shock and grief every bit as strong as it was initially. Indeed, each time he heard this news, he was hearing it “for the first time.” With no memory, he had no opportunity to live with the news, to adjust to it. Hence, his grief could not subside. Without memory, H.M. had no way to come to terms with his uncle's death.

A different glimpse of memory function comes from H.M.'s poignant comments about his state and about “who he is.” Each of us has a conception
H.M.'s Brain

H.M. died in 2008, and the world then learned his full name, Henry Molaison. Throughout his life, H.M. had cooperated with researchers in many studies of his memory loss. Even after his death, H.M. is contributing to science: His brain (shown here) was frozen and has now been sliced into sections for detailed anatomical study.

of who we are, and that conception is supported by numerous memories: We know whether we're deserving of praise for our good deeds or blame for our transgressions because we remember our good deeds and our transgressions. We know whether we've kept our promises or achieved our goals because, again, we have the relevant memories. None of this is true for people who suffer from amnesia, and H.M. sometimes commented on the fact that in important ways, he didn't know who he was. He didn't know if he should be proud of his accomplishments or ashamed of his crimes; he didn't know if he'd been clever or stupid, honorable or dishonest, industrious or lazy. In a sense, then, without a memory, there is no self. (For broader discussion, see Conway & Pleydell-Pearce, 2000; Hilts, 1995.)

What, then, is the scope of cognitive psychology? As we mentioned earlier, this field is sometimes defined as the scientific study of the acquisition, retention, and use of knowledge. We've now seen, though, that "knowledge" (and, hence, the study of how we gain and use knowledge) is relevant to a huge range of concerns. Our self-concept, it seems, depends on our knowledge (and, in particular, on our episodic knowledge). Our emotional adjustments
to the world, as we have seen, rely on our memories. Or, to take a much more ordinary case, our ability to understand a story we've read, or a conversation, or, presumably, any of our experiences, depends on our supplementing that experience with some knowledge.

The suggestion, then, is that cognitive psychology can help us understand capacities relevant to virtually every moment of our lives. Activities that don't, on the surface, appear intellectual would nonetheless collapse without the support of our cognitive functioning. The same is true whether we're considering our actions, our social lives, our emotions, or almost any other domain. This is the scope of cognitive psychology and, in a real sense, the scope of this book.

The Cognitive Revolution

The enterprise that we now call “cognitive psychology” is roughly 50 years old, and the emergence of this field was in some ways dramatic. Indeed, the science of psychology went through changes in the 1950s and 1960s that are often referred to as psychology’s “cognitive revolution,” and the revolution brought a huge shift in the style of research used by most psychologists. The new style was intended initially for studying problems we've already met: problems of memory, decision making, and so on. But this new type of research, and its new approach to theorizing, was soon exported to other domains, with the consequence that in important ways the cognitive revolution changed the intellectual map of our field.

The Limits of Introspection

The cognitive revolution centered on a small number of key ideas. One idea is that the science of psychology cannot study the mental world directly. A second idea is that the science of psychology must study the mental world if we are going to understand behavior.

As a path toward understanding each of these ideas, let's look at a pair of earlier traditions in psychology that offered a rather different perspective. We'll start with a research framework, prominent more than a century ago, that assumed we could study the mental world directly. Note, though, that our purpose here is not to describe the full history of modern cognitive psychology. That history is rich and interesting, but our goal is a narrow one—to explain why the cognitive revolution’s themes were as they were. (For readers interested in the history, though, see Bartlett, 1932; Benjamin, 2008; Broadbent, 1958; Malone, 2009; Mandler, 2011.)

In the late 19th century, Wilhelm Wundt (1832–1920) and his student Edward Bradford Titchener (1867–1927) launched a new research enterprise, and according to many scholars, it was their work that eventually led to the modern field of experimental psychology. In Wundt’s and Titchener’s view, psychology needed to focus largely on the study of conscious mental events—feelings, thoughts, perceptions, and recollections. But how should
these events be studied? These early researchers started with the obvious fact that there is no way for you to experience my thoughts, or I yours. The only person who can experience or observe your thoughts is you. Wundt, Titchener, and their colleagues concluded, therefore, that the only way to study thoughts is for each of us to introspect, or "look within," to observe and record the content of our own mental lives and the sequence of our own experiences.

Wundt and Titchener insisted, though, that this introspection could not be casual. Instead, introspectors had to be meticulously trained: They were given a vocabulary to describe what they observed; they were taught to be as careful and as complete as possible; and above all, they were trained simply to report on their experiences, with a minimum of interpretation.

This style of research was enormously influential for several years, but psychologists gradually became disenchanted with it, and it's easy to see why. As one concern, these investigators were soon forced to acknowledge that some thoughts are unconscious, and this meant that introspection was inevitably limited as a research tool. After all, by its very nature introspection is the study of conscious experiences, and so of course it can tell us nothing about unconscious events.

Indeed, we now know that unconscious thought plays a huge part in our mental lives. For example, what is your phone number? It's likely that the moment you read this question, the number "popped" into your thoughts without any effort, noticeable steps, or strategies on your part. But, in fact,
there's good reason to think that this simple bit of remembering requires a complex series of steps. These steps take place outside of awareness; and so, if we rely on introspection as our means of studying mental events, we have no way of examining these processes.

But there is also another and deeper problem with introspection: In order for any science to proceed, there must be some way to test its claims; otherwise, we have no means of separating correct assertions from false ones, accurate descriptions of the world from fictions. Hand in hand with this requirement, science needs some way of resolving disagreements: If you claim that Earth has one moon and I insist that it has two, we need some way of determining who is right. Otherwise, we cannot locate the facts of the matter, and so our "science" will become a matter of opinion, not fact.

With introspection, this testability of claims is often unattainable. To see why, imagine that I insist my headaches are worse than yours. How could we ever test my claim? It might be true that I describe my headaches in extreme terms: I talk about my "agonizing, excruciating" headaches. But that might mean only that I'm inclined toward extravagant descriptions; it might reflect my verbal style, not my headaches. Similarly, it might be true that I need bed rest whenever one of my headaches strikes. Does that mean my headaches are truly intolerable? It might mean instead that I'm self-indulgent and rest even in the face of mild pain. Perhaps our headaches are identical, but you're stoic about yours and I'm not.

How, therefore, should we test my claim about my headaches? What we need is some means of directly comparing my headaches to yours, and that would require transplanting one of my headaches into your experience, or vice versa. Then one of us could make the appropriate comparison. But (setting aside the science fiction notion of telepathy) there's no way to do this, leaving us, in the end, unable to determine whether my headache reports are exaggerated, distorted, or accurate. We're left, in other words, with the brute fact that our only information about my headaches is what comes to us through the filter of my description, and we have no way to know how (or whether) that filter is coloring the evidence.

For purposes of science, this is unacceptable. Ultimately, we do want to understand conscious experience, and so, in later chapters, we will consider introspective reports. For example, we'll talk about the subjective feeling of "familiarity" and the conscious experience of mental imagery; in Chapter 14, we'll talk about consciousness itself. In these settings, though, we'll rely on introspection as a source of observations that need to be explained; we won't rely on introspective data as a means of evaluating our hypotheses—because, usually, we can't. To test hypotheses, we need data we can rely on, and, among other requirements, this means we need data that aren't dependent on a particular point of view or a particular descriptive style. Scientists generally achieve this objectivity by making sure the raw data are out in plain view, so that you can inspect my evidence, and I yours. In that way, we can be certain that neither of us is distorting or misreporting or exaggerating the facts. And that is precisely what we cannot do with introspection.
The Years of Behaviorism

Historically, the concerns just described led many psychologists to abandon introspection as a research tool. Psychology could not be a science, they argued, if it relied on this method. Instead, psychology needed objective data, and that meant data that were out in the open for all to observe.

What sorts of data does this allow? First, an organism's behaviors are obviously observable in the right way: You can watch my actions, and so can anyone else who is appropriately positioned. Therefore, data concerned with behavior are objective data and, thus, grist for the scientific mill. Likewise, stimuli in the world are in the same "objective" category: These are measurable, recordable, physical events.

In addition, you can arrange to record the stimuli I experience day after day and also the behaviors I produce each day. This means that you can record how the pattern of behaviors changes with the passage of time and with the accumulation of experience. Thus, my learning history can also be objectively recorded and scientifically studied.

In contrast, my beliefs, wishes, goals, and expectations are all things that cannot be directly observed, cannot be objectively recorded. These "mentalistic" notions can be observed only via introspection; and introspection, we have suggested, has little value as a scientific tool. Hence, a scientific psychology needs to avoid these invisible internal entities.

It was this perspective that led researchers to the behaviorist theory movement, a movement that dominated psychology in America for the first half of the 20th century. This movement was a success in many ways and uncovered a range of principles concerned with how behavior changes in response to

JOHN B. WATSON

John B. Watson (1878–1958) was a prominent and persuasive advocate for the behaviorist movement. Given his focus on learning and learning histories, it is unsurprising that Watson was intrigued by babies' behavior and learning. Here, he tests the grasp reflex displayed by all human neonates.
various stimuli (including the stimuli we call "rewards" and "punishments"). By the late 1950s, however, psychologists were convinced that a lot of our behavior could not be explained in these terms. The reason, in brief, is that the ways people act, and the ways that they feel, are guided by how they understand or interpret the situation, and not by the objective situation itself. Therefore, if we follow the behaviorists' instruction and focus only on the objective situation, we will regularly misunderstand why people are doing what they're doing and make the wrong predictions about how they'll behave in the future. To put this point another way, the behaviorist perspective demands that we not talk about mental entities such as beliefs, memories, and so on, because these things cannot be studied directly and therefore cannot be studied scientifically. Yet it seems that these subjective entities play a pivotal role in guiding behavior, and so we must consider these entities if we want to understand behavior.

Evidence pertinent to these assertions is threaded throughout the chapters of this book. Over and over, we'll find it necessary to mention people's perceptions and strategies and understanding, as we strive to explain why (and how) they perform various tasks and accomplish various goals. Indeed, we've already seen an example of this pattern. Imagine that we present the "Betsy and Jacob" story to people and then ask them various questions: Why did Betsy shake her piggy bank? Why did she go to look for her mother? People's responses will surely reflect their understanding of the story, which in turn depends on far more than the physical stimulus—that is, the 29 syllables of the story itself. If we want to predict someone's responses to these questions, therefore, we'll need to refer to the stimulus (the story itself) and also to the person's knowledge and understanding of this stimulus.

Here's a different example that makes the same general point. Imagine you're sitting in the dining hall. A friend produces this physical stimulus: "Pass the salt, please," and you immediately produce a bit of salt-passing behavior. In this exchange, there is a physical stimulus (the words that your friend uttered) and an easily defined response (your passing of the salt), and so this simple event seems fine from the behaviorists' perspective: The elements are out in the open, for all to observe, and can easily be objectively recorded. But let's note that the event would have unfolded in the same way if your friend had offered a different stimulus. "Could I have the salt?" would have done the trick. Ditto for "Salt, please!"] or "Hmm, this sure needs salt!" If your friend is both loquacious and obnoxious, the utterance might have been, "Excuse me, but after briefly contemplating the gustatory qualities of these comestibles, I have discerned that their sensory qualities would be enhanced by the addition of a number of sodium and chloride ions, delivered in roughly equal proportions and in crystalline form; could you aid me in this endeavor?" You might giggle (or snarl) at your friend, but you would still pass the salt.

Now let's work on the science of salt-passing behavior. When is this behavior produced? Since we've just observed that the behavior is evoked by all of these different stimuli, we would surely want to ask: What do these stimuli have in common? If we can answer that question, we're well on our way to understanding why these stimuli all have the same effect.
If we focus entirely on the observable, objective aspects of these stimuli, they actually have little in common. After all, the actual sounds being produced are rather different in that long utterance about sodium and chloride ions and the utterance, “Salt, please!” And in many circumstances, similar sounds would not lead to salt-passing behavior. Imagine that your friend says, “Salt the pass” or “Sass the palt.” These are acoustically similar to “Pass the salt” but wouldn’t have the same impact. Or imagine that your friend says, “She has only a small part in the play. All she gets to say is, ‘Pass the salt, please.’” In this case, exactly the right syllables were uttered, but you wouldn’t pass the salt in response.

It seems, then, that our science of salt passing won’t get very far if we insist on talking only about the physical stimulus. Stimuli that are physically different from each other (“Salt, please” and the bit about ions) have similar effects. Stimuli that are physically similar to each other (“Pass the salt” and “Sass the palt”) have different effects. Physical similarity, therefore, is plainly not what unites the various stimuli that evoke salt passing.

It is clear, though, that the various stimuli that evoke salt passing do have something in common with each other: They all mean the same thing. Sometimes this meaning derives easily from the words themselves (“Please pass the salt”). In other cases, the meaning depends on certain pragmatic rules. (For example, we pragmatically understand that the question “Could you pass the salt?” is not a question about arm strength, although, interpreted literally, it might be understood that way.) In all cases, though, it seems plain that to predict your behavior in the dining hall, we need to ask what these stimuli mean to you. This seems an extraordinarily simple point, but it is a point, echoed over and over by countless other examples, that indicates the impossibility of a complete behaviorist psychology.1

The Roots of the Cognitive Revolution

It seems, then, that we’re caught in a trap: We need to talk about the mental world if we hope to explain behavior. This is because how people act is shaped by how they perceive the situation, how they understand the stimuli, and so on. The only direct means of studying the mental world, however, is introspection, and introspection is scientifically unworkable. Thus, in brief: We need to study the mental world, but we can’t.

There is, however, a solution to this impasse, and it was actually suggested many years ago by philosopher Immanuel Kant (1724–1804). To use Kant’s transcendental method, you begin with the observable facts and then work backward from these observations. In essence, you ask: How could these observations have come about? What must the underlying causes be that led to these effects?

---

1 We should note that the behaviorists themselves quickly realized this point. Hence, modern behaviorism has abandoned the radical rejection of mentalistic terms; indeed, it’s hard to draw a line between modern behaviorism and a field called “animal cognition,” a field that often employs mentalistic language. The behaviorism being criticized here is a historically defined behaviorism, and it’s this perspective that, in large measure, gave birth to modern cognitive psychology.
This method, sometimes called “inference to best explanation,” is at the heart of most modern science. Physicists, for example, routinely use this method to study objects or events that cannot be observed directly. To take just one case, no physicist has ever observed an electron, but this has not stopped physicists from learning a great deal about electrons. How do the physicists proceed? Even though electrons themselves are not observable, their presence often leads to observable results—in essence, visible effects from an invisible cause. Thus, among other things, electrons leave observable tracks in cloud chambers, and they produce momentary fluctuations in a magnetic field. Physicists can then use these observations the same way a police detective uses clues—asking what the “crime” must have been like if it left this and that clue. (A size 11 footprint? That probably tells us what size feet the criminal has, even though no one observed his feet. A smell of tobacco smoke? That suggests the criminal was a smoker. And so on.) In the same fashion, physicists observe the clues that electrons leave behind, and from this information they form hypotheses about what electrons must be like in order to have produced these specific effects.

Of course, physicists (and other scientists) have a huge advantage over a police detective: If the detective has insufficient evidence, she can’t arrange for the crime to happen again in order to produce more evidence. (She can’t say to the robber, “Please visit the bank again, but this time don’t wear a mask.”) Scientists, in contrast, can arrange for a repeat of the “crime” they’re seeking to explain. More precisely, they can arrange for new experiments, with new measures. Better still, they can set the stage in advance, to maximize the likelihood that the “culprit” (in our example, the electron) will leave useful clues behind. They can, for example, add new recording devices to the situation, or they can place various obstacles in the electron’s path. In this way, scientists can gather more and more data, including data that are crucial for testing the specific predictions of a particular theory. This prospect—of reproducing experiments and varying the experiments to test hypotheses—is what gives science its power. It’s what enables scientists to assert that their hypotheses have been rigorously tested, and it’s what gives scientists assurance that their theories are correct.

Psychologists work in the same fashion—and the notion that we could work in this fashion was one of the great contributions of the cognitive revolution. The idea, in essence, is simply this: We know that we need to study mental processes; that’s what we learned from the limitations of behaviorism. But we also know that mental processes cannot be observed directly; we learned that from the downfall of introspection. Our path forward, therefore, is to study mental processes indirectly, relying on the fact that these processes, themselves invisible, have visible consequences: measurable delays in producing a response, performances that can be assessed for accuracy, errors that can be scrutinized and categorized. By examining these (and other) effects produced by mental processes, we can develop—and then test—hypotheses about what the mental processes must have been. In this fashion, we use Kant’s method, just as physicists (or biologists or chemists or astronomers) do, to develop a science that does not rest on direct observation.
Research in Cognitive Psychology: The Diversity of Methods

In setting after setting, cognitive psychologists have applied the Kantian logic to explain how people remember, make decisions, pay attention, or solve problems. In each case, we begin with a particular performance—say, a memory task—and then hypothesize a series of unseen mental events that made the performance possible. But, crucially, we don't stop there. We also ask whether some other, perhaps simpler, sequence of events might explain the data or whether a different sequence might explain both these data and some other findings. In this fashion, we do more than ask how the data came about; we also seek the best way to think about the data.

For some data, the sequence of events we hypothesize resembles the processing steps that a computer might use. (For classic examples of this approach, see Broadbent, 1958; Miller, Galanter, & Pribram, 1960.) For other data, we might cast our hypotheses in terms of the strategies a person is using or the inferences she is making. No matter what the form of the hypothesis, though, the next step is crucial: The hypothesis is tested by collecting more data. Specifically, we seek to derive new predictions based on our hypothesis: “If this is the mechanism behind the original findings, then things should work differently in this circumstance or that one.” If these predictions are tested and confirmed, this outcome suggests that the proposed hypothesis was correct. If the predictions are not confirmed, then a new hypothesis is needed.

But what methods do we use, and what sorts of data do we collect? The answer, in brief, is that we use diverse methods and collect many types of data. In other words, what unites cognitive psychology is not an allegiance to any particular procedure in the laboratory. Instead, what unites the field is the logic that underlies our research, no matter what method is in use. (We discuss this logic more fully in the appendix for this textbook; the appendix contains a series of modules, “keyed” to individual chapters. Each module explores an aspect of research methodology directly related to its associated chapter.)

Let's explore this point with a concrete example. We'll return to this example in Chapter 6, where we'll put it into a richer context. For now, though, you shouldn't worry too much about the theory involved in this example; our focus here is on how the research unfolds.

Working Memory: Some Initial Observations

Many of the sentences in this book—including the one you are reading right now, which consists of 23 words—are rather long. In these sentences, words that must be understood together (such as “sentences . . . are . . . long”) are often widely separated (note the 16 words interposed between “sentences” and “are”). Yet you have no trouble understanding these sentences.

We begin, therefore, with a simple fact—that you are able to read, even though ordinary reading requires you to integrate words that are widely
separated on the page. How should we explain this fact? What is the (unseen) cause that leads to this (easily observed) fact? The obvious suggestion is that you’re relying on some form of memory that enables you to remember the early words in the sentence as you forge ahead. Then, once you’ve read enough, you can integrate what you have decoded so far. In this section’s very first sentence, for example, you needed to hang on to the first seven words (“Many of the sentences in this book”) while you read the interposed phrase (“including the one . . . 23 words”). Then, you had to bring those first seven words back into play, to integrate them with the sentence’s end (“are rather long”).

The form of memory proposed here is called working memory, to emphasize that this is the memory you use for information that you are actively working on. Working memory holds information in an easily accessible form, so that the information is, so to speak, at your fingertips, instantly available when you need it. This instant availability is promoted by several factors, including, quite simply, working memory’s size: Working memory is hypothesized to have a small capacity, and so, with only a few items held in this store, you will never have a problem locating just the item you want. (If you have only two keys on your key ring, it’s easy to find the one that unlocks your door. If you had a hundred keys on the ring, the situation would be rather different.)

Can we test this proposal? One way to measure working memory’s capacity is via a span test. In this test, we read to someone a list of, say, four items, perhaps four letters (“A D G W”). The person has to report these back, immediately, in sequence. If she succeeds, we try it again with five letters (“Q D W U F”). If she can repeat these back correctly, we try six letters, and so on, until we find a list that the person cannot report back accurately. Generally, people start making errors with sequences of seven or eight letters. Most people’s letter span, therefore, is about seven or eight. This finding confirms our hypothesis that working memory is limited in size; but more important for our purposes here, it also provides a simple example of how we can learn about this memory’s properties by seeing how this (unseen) memory influences observable performance.

Working Memory: A Proposal

As it turns out, the span test also puts another observation into view—another “effect” for which we need to seek a “cause.” Specifically, when we measure memory span, we find that people often make errors—they report letters that they hadn’t heard at all—and these errors follow a simple pattern: When people make mistakes in this task, they generally substitute one letter for another with a similar sound. Having heard “S,” they’ll report back “F”; or having heard “D,” they’ll report back “T.” The problem is not in hearing the letters in the first place: We get similar sound-alike confusions if the letters are presented visually. Thus, having seen “F,” people are likely to report back “S”; they are not likely, in this situation, to report back the similar-looking “E.”
This finding provides another clue about working memory’s nature, and two British researchers—Alan Baddeley and Graham Hitch—proposed a model to explain both this finding and many other results as well (e.g., Baddeley & Hitch, 1974, or, for a more recent treatment, see Baddeley, 2000). We’ll have more to say about their model later; but for now, the key idea is that working memory actually has several different parts, and so it’s more accurate to speak of the working-memory system. At the heart of the system is the central executive; this is the part that runs the show and does the real work. The executive is helped out, though, by low-level “assistants.” These assistants are not sophisticated; and so, if you need to analyze or interpret some information, the assistants can’t do it—the executive is needed for that. What the assistants can do, however, is provide storage, and this function, simple though it is, makes the assistants extremely useful.

Specifically, information that will soon be needed, but isn’t needed right now, can be sent off to the assistants for temporary storage. As a result, the executive isn’t burdened by the mere storage of this information and so is freed up to do other tasks. In effect, therefore, the assistants serve the same function as a piece of scratch paper on your desk. When you’re going to need some bit of information soon (a phone number, perhaps), you write it down on the scratch paper. Of course, the scratch paper has no mind of its own, and so it can’t do anything with the “stored” information; all it does is hold on to the information. But that’s helpful enough: With the scratch paper “preserving” this information, you can cease thinking about it with no risk that the information will be lost. This enables you to focus your attention more productively on other, more complex chores. Then, when you’re ready for the stored information (perhaps just a moment later), you glance at your note, and there the information will be.

Working memory’s assistants provide the same benefit, and one of the most important assistants is the articulatory rehearsal loop. To see how it works, try reading the next few sentences while holding on to this list of numbers: “1, 4, 6, 4, 9.” Got them? Now read on. You are probably repeating the numbers over and over to yourself, rehearsing them with your inner voice. But this turns out to require very little effort, so you can continue reading while doing this rehearsal. Nonetheless, the moment you need to recall the numbers (what were they?), they are available to you. How did you do this? The numbers were maintained by working memory’s rehearsal loop, and with the numbers thus out of the way, the central executive was free to continue reading. And that is the advantage of this system: With storage handled by the helpers, the executive is available for other, more demanding tasks.

To launch the rehearsal loop, you rely on the process of subvocalization—silent speech. In other words, you quietly say the numbers to yourself. This “inner voice,” in turn, produces a representation of these numbers in the phonological buffer. In other words, an auditory image is created in the “inner ear” (see Figure 1.1). This image will fade away after a second or two, but before it does, subvocalization can be used once again to create a new image, sustaining the material in this buffer.
Working memory's central executive is supported by a number of low-level assistants. One assistant, the articulatory rehearsal loop, involves two components: subvocal speech (the "inner voice") and a phonological buffer (the "inner ear"). Items are rehearsed by using subvocalization to "load" the buffer. While this is going on, the executive is free to work on other matters.

Evidence for the Working-Memory System

Baddeley and Hitch proposed their model as an explanation for the available evidence; it was, in their view, the best way to explain the facts collected so far. For example, why do people make "sound-alike" errors in a span task? It's because they're relying on the rehearsal loop, which involves a mechanism (the "inner ear") that stores the memory items as (internal representations of) sounds, and so it's no surprise that errors, when they occur, are shaped by this mode of storage.

Notice, then, that we're using the Kantian logic described earlier: generating a hypothesis about unseen mechanisms (e.g., the operation of the rehearsal loop) in order to explain visible data (e.g., the pattern of the errors).
The mechanisms needed to control subvocal speech (the "inner voice") overlap significantly with those needed for the control and production of overt speech. Therefore, if these mechanisms are in use for actual speech, they are not available for subvocal rehearsal. Hence, many experiments block rehearsal by requiring participants to say "Tah-Tah-Tah" out loud.

Crucially, though, this hypothesis also leads to many new predictions, and this enables us to test the hypothesis—by asking whether its predictions are accurate. It is this step that turns a "mere" hypothesis into solid scientific knowledge.

For example, imagine that we ask people to take the span test while simultaneously saying "Tah-Tah-Tah" over and over, out loud. This concurrent articulation task obviously requires the mechanisms for speech production. Therefore, these mechanisms are not available for other use, including subvocalization. (If you’re directing your lips and tongue to produce the “Tah-Tah-Tah” sequence, you can’t at the same time direct them to produce the sequence needed for the subvocalized materials; see Figure 1.2.)
According to the model, how will this constraint matter? First, note that our original span test measured the combined capacities of the central executive and the loop. That is, when people take a span test, they store some of the to-be-remembered items in the loop and others via the central executive. (This is a poor use of the executive, underutilizing its talents, but that's okay here, because the span task doesn't demand anything beyond mere storage.) With concurrent articulation, though, the loop isn't available for use, and so we are now measuring the capacity of working memory without the rehearsal loop. We should predict, therefore, that concurrent articulation, even though it's extremely easy, should cut memory span drastically. This prediction turns out to be correct. Span is ordinarily about seven items; with concurrent articulation, it drops by roughly a third—to four or five items (Chincotta & Underwood, 1997; see Figure 1.3).

**FIGURE 1.3 THE EFFECT OF CONCURRENT ARTICULATION ON SPAN**

In the Control condition, people were given a normal digit-span test. In the Suppression condition, people were required to do concurrent articulation while taking the test. Concurrent articulation is easy, but it blocks use of the articulatory loop and consistently decreases memory span, from roughly seven items to five or so. And plainly this use of the articulatory loop is not an occasional strategy; instead, it can be found in a wide range of countries and languages. After Chincotta & Underwood, 1997.
Second, with visually presented items, concurrent articulation should eliminate the sound-alike errors. Repeatedly saying “Tah-Tah-Tah” blocks use of the articulatory loop, and it is in this loop, we’ve proposed, that the sound-alike errors arise. This prediction, too, is correct: With concurrent articulation and visual presentation of the items, sound-alike errors are largely eliminated.

Third, we can also test people’s memory spans by using complex visual shapes. People are shown these shapes and then must echo the sequence back by drawing what they have just seen. If we choose shapes that are not easily named, then the shapes cannot be rehearsed via the inner-voice/inner-ear combination. (What would you subvocalize to rehearse them?) With these stimuli, therefore, there should be no effect of concurrent articulation: If people aren’t using the rehearsal loop, there should be no cost attached to denying them use of the loop. This prediction is also correct.

Finally, here is a different sort of prediction. We have claimed that the rehearsal loop is required only for storage; this loop (like all of working memory’s assistants) is incapable of any more sophisticated operations. Therefore, these other operations should not be compromised if the loop is unavailable. This, too, turns out to be correct: Concurrent articulation blocks use of the loop but has no effect on someone’s ability to read brief sentences, to do simple logic problems, and so on. (Blocking use of the loop does have an effect when you’re reading more complex sentences or doing harder problems; that’s because these harder tasks require analysis and the storage of interim steps, and so require the entire working-memory system—the executive and the assistants.)

The Nature of the Working-Memory Evidence

No one has ever seen the “inner voice” or the “inner ear” directly. Nonetheless, we’re confident that these entities exist, because they are essential parts of our explanation for the data and—crucially—there seems to be no other way to explain the data. Moreover, our claims about the inner voice and the inner ear have consistently led us to new predictions that have been confirmed by further testing. In this way, our claims have been useful (leading to new observations) as well as accurate (leading to correct predictions).

Let’s note also that in supporting our account, there are many forms of data available to us. We can manipulate research participants’ activities, as we did with concurrent articulation, and then we can look at how this manipulation changes their performance (e.g., the size of the measured memory span). We can also manipulate the stimuli themselves, as we did in testing memory for visual shapes, and see how this changes things. We can also look in detail at the nature of the performance, asking not just about someone’s overall level of success in our tasks but also about his or her specific errors (sound-alike vs. look-alike). We can also measure the speed of participants’ performance and ask how it is influenced by various manipulations. We do this, for example, when we ask whether problem solving is compromised by
concurrent articulation. The assumption here is that mental processes are very fast but nonetheless do take a measurable amount of time. By timing how quickly participants answer various questions or perform various tasks, we can ask what factors speed up mental processes and what factors slow them down.

We can also gather data from another source. So far, we've been concerned with people's performance on our tasks—for example, how much or how well they remember. There's much to learn, though, by considering the biological mechanisms that make this performance possible. That is, we can draw evidence from the realm of cognitive neuroscience—the study of the biological basis for cognitive functioning.

For example, what exactly is the nature of subvocalization? Is it just like actual speech, but silent? If so, does it involve movements (perhaps tiny movements) of the tongue, the vocal cords, and so on? One way to find out would be to paralyze the relevant muscles. Would this action disrupt use of the rehearsal loop? As it turns out, we don't have to perform this experiment; nature has performed it for us. Because of specific forms of neurological damage, some individuals have no ability to move these various muscles and so suffer from anarthria—an inability to produce overt speech. Data indicate, however, that these individuals show sound-alike confusions in their span data, just as ordinary participants do; they also show other results (e.g., something called "the word-length effect") associated with the use of the rehearsal loop (e.g., Vallar & Cappa, 1987). These observations suggest that actual muscle movements aren't needed for subvocalization, because the results are the same without these movements. It seems likely, therefore, that "inner speech" relies on the brain areas responsible for planning and controlling the muscle movements of speech and not on the movements themselves. This is by itself an interesting fact, but for present purposes, let's note the use of yet another type of data: observations from neuropsychology, concerned with how various forms of brain dysfunction influence observed performance.

We can pursue related questions by examining the brain activity of people with fully intact (undamaged) brains. Recent developments in brain-imaging technology tell us that when a participant is engaged in working-memory rehearsal, considerable activity is observed in brain areas that we know (from other evidence) are crucially involved in the production of spoken language, as well as in areas that play an important role in the perception of spoken language. These findings suggest that claims about the "inner voice" and "inner ear" are more than casual metaphors; instead, the "inner voice" uses brain mechanisms that are ordinarily used for overt speech, and the "inner ear" uses mechanisms ordinarily used for actual hearing (cf. Jonides, Lacey, & Nee, 2005; for more on the neuroscience of working memory, see Jonides et al., 2008).

We can also gain insights by comparing diverse populations—for example, by comparing people who speak different languages (see Figure 1.3), or comparing people with normal hearing to people who have been deaf since
Verbal memory

Spatial memory

Left lateral Superior Right lateral

BRAIN ACTIVITY AND WORKING-MEMORY REHEARSAL

Color is used here as an indication of increased brain activity (measured in this case by positron emission tomography). When people are engaged in a verbal memory task (and so using the articulatory loop), activation increases in areas ordinarily used for language production and perception. A very different pattern is observed when people are engaged in a task requiring memory for spatial position.

birth and who communicate via sign language. It turns out, for example, that the deaf rely on a different assistant for working memory: They use an “inner hand” (and covert sign language) rather than an “inner voice” (and covert speech). As a result, they are disrupted if they are asked to wiggle their fingers during a memory task (akin to a hearing person saying “Tah-Tah-Tah”), and they also tend to make “same-hand-shape” errors in working memory (analogous to the sound-alike errors made by the hearing population). These results speak not only to the generality of the claims made here but also to the need to fine-tune these claims when we consider other groups of people.

Finally, let’s emphasize the importance of building our argument with multiple lines of evidence. That’s because, in most cases, no single line of evidence is decisive by itself. There are, after all, probably other ways to explain our initial observations about span, if those results were all we had to go on. There are also other ways to explain the other individual findings we have mentioned, if these likewise were considered in isolation. It’s only when we take the results as a package that we can make headway, and if we have done our work well, there will be just one theoretical account that fits with the entire data pattern. At that point, with no other way to explain the
THE INNER HAND, RATHER THAN THE INNER VOICE

People who can speak and hear rely on the articulatory rehearsal loop as part of the working-memory system. As a result, errors in working memory are often "sound-alike errors." Members of the deaf community, in contrast, rely on a "signing rehearsal loop," using an "inner hand" rather than an "inner voice." Their errors often involve confusions between different words that happen to have similar hand shapes when expressed in sign language.

Working Memory in a Broader Context

Having made all of these methodological points, let's round out this section with one final comment. We introduced the example of working memory in order to showcase the diversity of methods used in cognition research. But we can also use working memory to make another point, one that allows us to replay an issue that we have already discussed.

Why should you care about the structure of working memory? The memory-span task itself seems quite unnatural: How often do you need to memorize a set of unrelated letters? For that matter, how often do you need to work on a problem while simultaneously saying "Tah-Tah-Tah" over and over? In short, what does this task, or this procedure, have to do with things you care about?

The answer to these questions lies in the fact that you rely on working memory in a vast number of circumstances; and so, if we understand working memory, we move toward an understanding of this far broader set of problems and issues. For example, bear in mind our initial comments about the role of working memory in reading or in any other task in which you must store early "products," keeping them ready for integration with later "products." One might imagine that many tasks have this character; reading, reasoning, and problem solving are a few. If you make effective use of working memory, therefore, you will have an advantage in all of these domains. Indeed, some scholars have suggested that "intelligence" in many domains amounts to nothing more than having a larger capacity in working memory. (We'll return to this point in Chapter 13.)

In a similar vein, the use of articulatory rehearsal seems a simple trick—one you use spontaneously, a trick in which you take no special pride. But it is a trick you had to learn, and young children, for example, often seem not to know it. There is some indication that this lack can be a problem for these children in learning to read: Without the option of relying on articulatory rehearsal, reading becomes much more difficult. It also appears that the rehearsal loop plays an important role when someone is learning new vocabulary, including vocabulary in a new language (Baddeley, Gathercole, & Papagno, 1998; Gathercole, Service, Hitch, Adams, & Martin, 1999;
Majerus, Poncelet, Elsen, & van der Linden, 2006). So here, too, is an important function of the working-memory system.

These examples can easily be multiplied, but by now the point should be clear: Working memory and articulatory rehearsal are relevant to a wide range of mental activities in adults and in children. Understanding working memory, therefore, may give us insight into a broad range of tasks. Similar claims can be made about many other cognitive resources: By understanding what it means to pay attention, we move toward an understanding of all the contexts in which attention plays a role. By understanding how we comprehend text, or how we use our knowledge to supplement our perceptions, we move toward an understanding of all the contexts in which these abilities play a part. And in each case, the number of such contexts is vast.

We end this chapter, therefore, by echoing a comment we have already made: The machinery of cognition is essential to virtually all of our waking activities (and perhaps some of our sleeping activities as well). The scope of cognitive psychology is broad indeed, and the relevance of our research is wide.

**APPLYING COGNITIVE PSYCHOLOGY**

Research in cognitive psychology helps us understand deep theoretical issues, such as what it means to be rational or what the function of consciousness might be. But our research also has practical implications, and studies often provide lessons for how we should conduct many aspects of our day-to-day lives.

To help you see these implications—and so to help you understand just how important our research is—each chapter in this text ends with an essay on one of the applications of cognitive psychology. In all cases, the essay explores how the material in that chapter can be applied to a real-world concern.

Some of the pragmatic lessons from cognitive psychology are obvious. For example, research on memory can help students who are trying to learn new materials in the classroom; studies of how people draw conclusions can help people to draw smarter, more defensible conclusions. Following these leads, many of the end-of-chapter essays are aimed at educational issues. The essay at the end of Chapter 4, for example, will teach you how to speed-read (but will also explain the limitations of speed-reading). The essay at the end of Chapter 6 offers concrete suggestions for how you should study the material you’re hoping to learn.

Other implications of our work, though, are more surprising. Consider, for example, the implications of cognitive psychology for the criminal justice system. More specifically, think about what happens in a criminal investigation. Eyewitnesses provide evidence, based on what they paid attention to during a crime and what they remember. Police officers question the witnesses, trying to maximize what each witness recalls—but without leading the witness in any way. Then the police try to deduce, from the evidence, who
the perpetrator was. Then later, during the trial, jurors listen to evidence and make a judgment about the defendant’s innocence or guilt.

Cast in these terms, it should be obvious that an understanding of attention, memory, reasoning, and judgment (to name just a few processes) is directly relevant to what happens in the legal system. It’s on this basis, therefore, that some of the end-of-chapter essays focus on the interplay between cognitive psychology and the law. The essay at the end of Chapter 3, for example, uses what we know about visual perception to ask what we can expect witnesses to see. The essay for Chapter 7 explores a research-based procedure for helping witnesses to recall more of what they’ve observed.

Of course, cognitive psychology also has implications for other domains—the practice of medicine, for example, or the training of businesspeople. One reason I focus on the justice system, though, is my own involvement with these issues: As a psychologist specializing in memory, I consult with police, lawyers, and the courts on questions about eyewitness evidence. This work has made it clear for me just how important our science is, and it also provides a constant reminder that we need to be careful in our work—so that we don’t mislead the courts with unfounded advice. I hope these essays will persuade you of the same crucial points.

COGNITIVE PSYCHOLOGY AND THE CRIMINAL JUSTICE SYSTEM

Eyewitnesses in the courtroom are relying on what they remember about the key events, and what they remember depends crucially on what they perceived and paid attention to. Therefore, our understanding of memory, perception, and attention can help the justice system in its evaluation of witness evidence.
Cognitive psychology is concerned with how people remember, pay attention, and think. The importance of all these issues arises in part from the fact that most of what we do, think, and feel is guided by things we already know. One example is the comprehension of a simple story, which turns out to be heavily influenced by the knowledge we supply.

Cognitive psychology emerged as a separate discipline in the late 1950s, and its powerful impact on the wider field of psychology has led many academics to speak of this emergence as the cognitive revolution. One predecessor of cognitive psychology was the 19th-century movement that emphasized introspection as the main research tool for psychology. Psychologists soon became disenchanted with this movement, however, for several reasons: Introspection cannot inform us about unconscious mental events; even with conscious events, claims rooted in introspection are often untestable because there is no way for an independent observer to check on the accuracy or completeness of an introspective report.

The behaviorist movement rejected introspection as a method, insisting instead that psychology speak only of mechanisms and processes that were objective and out in the open for all to observe. However, evidence suggests that our thinking, behavior, and feelings are often shaped by our perception or understanding of the events we experience. This is problematic for the behaviorists: Perception and understanding are exactly the sorts of mental processes that the behaviorists regarded as subjective and not open to scientific study.

In order to study mental events, psychologists have turned to a method in which one focuses on observable events but then asks what (invisible) events must have taken place in order to make these (visible) effects possible.

Research in working memory provides an example of how cognitive psychologists use evidence. One theory of working memory proposes that this memory consists of a central executive and a small number of low-level assistants, including the articulatory rehearsal loop, which stores material by means of covert speech. Many forms of evidence are used in supporting this account: measures of working memory’s holding capacity in various circumstances, the nature of errors people make when using working memory, the speed of performance in working-memory tasks, evidence drawn from the study of people with brain damage, and evidence drawn from brain-imaging technology.

**eBook Demonstrations & Essays**

Online Demonstrations:
- Demonstration 1.1: The Articulatory Rehearsal Loop
- Demonstration 1.2: Sound-Based Coding

Online Applying Cognitive Psychology Essays:
- Cognitive Psychology and Education: Enhancing Classroom Learning

**ZAPS 2.0 Cognition Labs**

Go to [http://digital.wwnorton.com/cognition6](http://digital.wwnorton.com/cognition6) for the online labs relevant to this chapter.