CHAPTER 1

Introduction to the Study of Memory

Remembering is a part of our every waking moment. Nearly everything we do throughout the day, including dreaming at night, involves memory. Consider the very act of waking up itself. As the alarm goes off, you must remember if you have an early appointment. If you do, you must get up right away, but if you do not, you can hit the snooze button and sleep a bit longer. Once you do get out of bed, even more is asked of your memory. Did you wear the same shirt on the same day last week? Would people notice? Are you going to the gym after classes? If so, do you need to bring workout clothes or are they already in your car? If you live in a dorm, you might try to remember if your roommate is in class already or trying to catch up on sleep. If you have a job, do you have any meetings that you cannot miss? These are just a few of the needs for memory within just a few moments of waking up. As the day proceeds, we have to remember how to drive to the university, the material for class that day, how to get from one classroom to another and what rooms are classes are in, where the car is parked so we can drive home, and the best route to get home in afternoon traffic. And this is just the beginning. You have to remember which friend you are meeting for lunch and where. Did this friend just break up with her boyfriend or are they back together? Remembering this is crucial in how you start your conversation with your friend. And, yes, did you forget that you had an exam in your social psychology class? You need to remember all the material you have been studying for the past few days. You can see how critical good memory performance is.

Memory also forms the basis of our views of our selves and our personalities. Think of how crucial your memory is to your sense of self and personality. Most of us, for example, like to think of ourselves as generous. But when was the last time you engaged in a truly generous act? Do you remember it? Being able to recall the characteristics of our own personality and back it up with actual memories is an important part of developing our sense of self. Certainly, early memories from childhood tend to be an important part of personality and sense of self as well. Almost all of us can describe poignant memories that shaped who we are today. For example, on the positive side, it might be the memory of a grandparent
telling us to be confident and do our best, or it might be the memory of a teacher who inspired us in grade school. On the other hand, a memory of the first time you saw a dead body in an auto accident may be instrumental in keeping you a safe driver, or your memory of the events of 9/11 may shape your view of world politics. Each of us has important memories like these.

Another way to view the importance of memory in our society is to “google” it. I just did and got nearly half a billion hits. Now some of these deal with computer memory, not our own memory, but just a quick search of the web yields vast numbers of sites that offer ways in which to improve your memory. I am hoping that this book will help guide you to those based on scientific evidence.

Moreover, the thought of losing or forgetting certain memories is scary and painful. Imagine losing access to all the memories of your dear grandmother. These memories are “treasures” in a way more closely connected to our sense of self than any bracelet or ring. Losing these memories, even the bad ones, is seen as devastating. Capitalizing on this fear, movies abound in fictional tales of amnesiacs, who lose not just their ability to learn (common in amnesia in the real world) but also the memory of the personal past and hence their personalities (less common in the real world). What makes the amnesia plot compelling is the knowledge of how important the personal past is to the present self.

For students, memory is also one’s livelihood. One’s job is to learn and remember a myriad range of information. Facts, dates, authors, concepts, methodologies, hypotheses, theories, and philosophies all must be learned and remembered. Doing so efficiently is important to many students who have many conflicting obligations. One of the goals of this textbook is to help students use their memory more efficiently. Because learning and memory are a student’s tools for advancement, managing one’s learning is a valuable skill. So for a student, memory is even more crucial in daily life.

For this reason, students could potentially perform better in school with some training in the best ways to use their memory. However, students are seldom given any formal training in learning and memory, especially training supported by scientific research. We place tremendous demands on the memories of students. But, aside from the class that you are likely taking and this book, we provide little scientific information about how memory works and how we can improve upon our ability to encode, store, and retrieve information. One goal for this book is to provide students with some knowledge about the current state of memory science and what psychological science and neuroscience can tell us about the nature of human memory. Another goal in this book is to provide students with concrete ways of applying what we know from science to improve their own abilities to learn and remember. Yes, this book is a textbook, detailing the current state of memory science. As important as advice is on the topic of how to improve memory, first must come the science. Thus, more words in this textbook will be devoted to the science of memory than the wherewithal of memory improvement. But I hope that the students reading this book will be able to improve their own learning by gathering useful strategies from the sections on memory improvement as well as personalized strategies through your own interpretations of theory and data. Indeed, the final chapter is completely devoted to memory improvement. Some readers may want to read the last chapter first.
THE SCIENCE OF MEMORY

We will approach the study of human memory from a scientific perspective. What does the term scientific perspective mean? In a broad sense, science refers to a particular view of the world, one based on systematic observation, experimentation, and theory. Critical to science is an unbiased attitude. A scientist needs to be open to different points of view but follow his or her data to the most logical conclusions, which are based on evidence, not on his or her opinion. In science, a particular theory is useful only if careful and unbiased observations and experimentation support it. For psychological science, like biology, data derived from experiments constitute the building blocks of our theories. Our intuitions and guesses about the world have value, but in order to be science, they must be tested and verified via the scientific method (for further information on this topic, go to www.sagepub.com/schwartz). 1

Empirical evidence is the product of scientific research. In order to be empirical evidence, it must be verifiable; that is, another scientist should be able to get the same results if he or she does the same or similar experiment. Empirical evidence is the building block for scientific theory. For example, in earth science, there is overwhelming empirical evidence that, as of 2011, the world’s climate is warming. Yes, there are many warming deniers, but these deniers do not examine the empirical evidence. In contrast, empirical evidence, by itself, does not inform us how to act. For example, with respect to global warming, some may advocate making changes in human industrial activity so as to reduce this warming trend, whereas others may make claims that we have to adjust to it but do not need to eliminate the warming pattern. Both may agree on the basic empirical evidence—that globally, temperatures are rising—but disagree on what governments should do about it.

In memory science, empirical evidence is the results of experiments. For this reason, this textbook will devote much space and words to the methods and results of experiments. Interpretations of what these experiments mean may vary, and you may find different opinions in other textbooks out there, but you will find that we all rely on the same empirical evidence. These experiments form the basis of memory science. In making recommendations about ways in which to boost memory performance, I will rely on only those methods that have been put to the scientific test and for which empirical evidence is available. This is not to deny that there may be performance boosters out there that we do not know about yet, but this textbook will only include empirically tested sources. I will also try to make these principles easier to understand by giving examples and telling a story or two. But stories and anecdotes do not constitute science—even though they may assist good pedagogy. So, please keep in mind the following: Experiments and empirical evidence form the basis of what we know about human memory from a scientific perspective.

The goal of memory science is to make generalizations about how memory works in the real world but by studying it under careful and controlled laboratory conditions. Thus, a researcher might be interested in how witnesses remember what they saw during a crime
and how accurate their memory is for that event. But memory researchers cannot follow the police around and interview witnesses at the crime scenes as the police are trying to do their jobs. This would be neither good science nor helpful in running a criminal justice system. Nor can memory researchers “hang around” in places where crimes might occur. This would be dull tedious work because, except in movies, convenience stores are rather safe places, nor do brawls break out every night in every bar. And if the memory researcher were to witness a crime, it might also be dangerous for that researcher. We can, however, ask people to come to labs, where they may see an acted film clip of a convenience store robbery and then look at simulated mug shots. This, by and large, simulates the conditions that people might encounter when witnessing a crime but in a safe and controlled manner. The control involved also allows for careful experimentation, which produces valuable empirical evidence. Control over the conditions is not just a safety measure; as we will see, it also allows us to make causal connections between variables.

Memory researchers are occasionally able to conduct field studies in which they study memory in the real world, including memories for crimes (Yuille & Cutshall, 1986). These studies usually confirm what has occurred in the lab. One hundred twenty-five years of research in the lab on memory have yielded a strong body of knowledge that applies in the real world as well as the lab. Thus, in this book, we will focus on scientific research and assume that, by and large, what we learn in the lab is applicable in everyday life.

Before we spend most of the book discussing the latest data and most up-to-date theories, let’s take a quick look at the history of memory science.

THE HISTORY OF MEMORY RESEARCH

Human beings have most likely been wondering about their own memories and how they work since prehistoric times. Early human beings have shown evidence of introspective behaviors as long ago as 40,000 years ago. We know from cave paintings as far afield as China, South Africa, and France that people were adorning themselves with body painting and jewelry, creating art, and presumably developing religious beliefs that long ago (see Figure 1.1). It is likely, though unproven, that some of their art reenacts memories of great hunting stories. Thus, it is likely that some of these Paleolithic people thought about their own memories.

Certainly, people have been writing about memory since the beginning of writing itself. Some of the oldest writing in the world records information about human memory. Ancient Egyptian medical manuals, known as Ebers Papyrus, from 1500 BCE (that is 3,500 years ago) describe the nature of memory deficits after injury (Scholl, 2002). Nearly 2,500 years ago, in classical Greece, Plato and Aristotle described theories of memory that sound surprisingly modern. Many philosophers and medical professionals wrote about the nature of memory during the ensuing millennia.

Memory metaphors are verbal models of how memory works. The great philosopher Plato (428–347 BCE) described two metaphors to account for memory. First, he compared human memory to a wax tablet. As learning occurs, information gets written into memory, as writing would get pressed into a wax tablet. Although the technology is outdated, this metaphor allows memory to be encoded, retrieved, and altered if the wax gets altered. Second, Plato also compared human memory retrieval to a bird cage. We reach our hands
into a cage to remove a bird, just as we reach into our memory to retrieve a particular event or item. Sometimes the memory may be difficult to retrieve, just as the bird may be difficult to catch. More recently, your author compared memory to a teenager’s room. It may appear disorganized, but the person knows where to find things. Roediger (1980) provides an excellent review of memory metaphors throughout history.

Particularly influential in the later development of a scientific approach to memory were the British associationists. Philosophers such as John Locke and George Berkeley emphasized how the mind creates associations between one idea and another. Their philosophy shaped much of the original science on human memory. However, the scientific method was not applied to the study of memory until a mere 125 years ago when German psychologist Hermann Ebbinghaus (1885/1965) published a volume titled *Memory: A Contribution to Experimental Psychology*. So our history will start with him.

**Hermann Ebbinghaus**

Until Ebbinghaus published his book, experimental psychology had confined itself to exploring the nature of sensation and perception. Ebbinghaus was the first person to use scientific methods to study memory and, indeed, the first person to use the experimental method to address issues of higher cognition. Ebbinghaus is remembered today because he
was the first memory psychologist but also because he established a number of principles of memory, which are still relevant today, both in terms of theory and application. Indeed, a number of his findings are directly applicable to the goals of memory improvement.

Most memory experiments today sample a large number of people. A memory experiment run on college students might test anywhere from 20 to 200 participants, depending on the nature of the experiment. Even studies today on special populations (infants, older adults, individuals with brain damage, etc.) will try to get at least several participants. But Ebbinghaus used only one test participant—himself. Of course, we now know that simply testing one person leads to questionable generalizations to others and is not necessarily a good way to conduct science. Luckily, although Ebbinghaus was a pioneering memory scientist, his own memory was rather ordinary. The experiments that he conducted on himself have since been tested on many other individuals, and what Ebbinghaus found in his 1885 study generalizes to other people.

Ebbinghaus taught himself lists of **nonsense syllables**. These nonsense syllables consisted of consonant-vowel-consonant trigrams, which lacked meaning in Ebbinghaus’s native German. In English, nonsense syllable trigrams might be TOB or HIF. They are pronounceable as they follow the rules of English word formation, but they do not mean anything in everyday speech. Ebbinghaus created and studied more than 2,000 of these trigrams over the course of his experimental study. Ebbinghaus chose nonsense syllables over words because he did not want meaning to shade his results. He assumed that meaningful stimuli would be more memorable than nonmeaningful stimuli, and he wanted a set of material that did not differ with respect to meaning.

Ebbinghaus would prepare a list of nonsense syllables, perhaps a list of 20 items. Nonsense syllables were ordered into lists. Ebbinghaus constructed lists of nonsense syllables as short as 6 syllables and as long as 20. He would then study this list of items until he could free recall all of the nonsense syllables on the list. Later, he would test himself—to see how many trigrams he could remember from each list. Not surprisingly, he found it was easier to master the shorter lists than the longer ones. This is true of memory in general—shorter lists are easy to master than longer lists. I often wonder what his neighbors must have thought of this young eccentric, long-bearded philosophy professor endlessly reciting nonsense syllables in his garret in Berlin.

His next experiment was to vary the **retention interval** between when he studied a list and when he retrieved that list. A retention interval is the time between when an item is initially learned or encoded and when it is retrieved or remembered. In Ebbinghaus’s case, he varied the time between his completion of mastering a particular list and when he tested himself again for that list. He found that the longer the retention interval, the more likely he was to forget items from that particular list. After a retention interval...
interval of just a few minutes, he might remember all of the syllables from a list. But if he waited a week, he might have forgotten a substantial number of items. This is another truism in memory—the longer the amount of time between learning and remembering, the more that will be forgotten.

Ebbinghaus investigated the phenomenon of **overlearning**. Overlearning is defined as studying after material has been thoroughly learned. In some of his experiments, Ebbinghaus studied some lists until he mastered the list (that is, could recall all of the items), then put that list aside until it was time to test himself for that list. For other lists, he continued to study the list even after he scored 100% on retrieving it during practice. He even varied the amount of time that he studied a list after he had achieved 100% performance on that list. He found that if he overlearned a list, his forgetting curve was less steep. That is, if he studied past the point of mastery, his forgetting of that list was slowed considerably. Thus, if he had studied a list on Day 1 to 100% accuracy and then stopped, his performance on that list might be 50% the next day. However, if he overlearned the list on Day 1, his performance would be better, perhaps 75%, the next day. Thus, studying past the point of mastery led

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**Savings score**: the reduction in time required to relearn a previously mastered list.

**Overlearning**: studying after material has been thoroughly learned.

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Ebbinghaus measured this forgetting by looking at the **savings score**. Savings meant the reduction in the amount of time required to relearn the list. If it had initially taken 10 repetitions per item to learn the list, it might take only 5 repetitions to relearn the list. Even if he could no longer remember any items from a previously studied list, Ebbinghaus demonstrated savings; it took him less time to relearn the list than it had to learn the list initially. Although savings diminished with retention interval, no matter how long the retention interval was, there was always some evidence of savings. More recently, Bahrick (1984) showed that there are savings for high school Spanish and French even 25 years after the last time a student took those courses. The choice of measurement, namely savings, allowed Ebbinghaus to examine some other characteristics of memory as well.
Another variable studied by Ebbinghaus was the distribution of study time. For some lists, he studied the lists all at once until he mastered them (massed practice). For other lists, he distributed his study over a series of lists and a series of days (distributed practice). But he measured the amount of time and the number of rehearsals he needed to learn each list individually. Thus, even if he was distributing his practice over several lists on one day, he would record the time for each list separately. This allowed him later to compare how many rehearsals and how much time it took for him to master each list.

Ebbinghaus found that if he had studied a massed-practice or distributed-practice list the same amount of time (but under different schedules), there were different savings scores for the lists. The distributed lists demonstrated higher savings scores at the same level of practice. This is now called the spacing effect, or the advantage of distributed practice over massed practice. Even though equal amounts of time went into study, those lists that were spaced showed a higher savings score than those that were studied all at once. Moreover, it took less total time to master a list that had been given distributed practice than one that received massed practice. This effect is also relevant today. Indeed, one of the crucial memory improvement hints given in the book is to take advantage of the spacing effect. Modern studies show that distributed practice can produce enormous boosts in the amount remembered per amount of time studied relative to massed practice. Indeed, if students can do only one thing to help their learning, it would be this one. And Ebbinghaus discovered it in the 19th century.

As you can see, Ebbinghaus’s work is still important and relevant and provides the basis for the first two mnemonic improvement hints in the book. After finishing his studies on memory and writing his book on the topic, Ebbinghaus himself moved on to other
interests and did not return to the study of memory. But for all those who followed, interested in the scientific pursuit of memory, Ebbinghaus laid the groundwork for memory science with solid methodology and important findings. For the complete text of Ebbinghaus's book, you can go to www.sagepub.com/schwartz.²

Mary Calkins

Shortly after the publication of Ebbinghaus's book, American psychologist Mary Calkins (who became the first woman president of the American Psychological Association) began her seminal study on the nature of associative learning, that is, how we pair new knowledge to existing knowledge. Calkins did this by examining paired-associate learning. Calkins (1894) had her participants study cue-target pairs of various types. In some cases, they were word-word pairs (e.g., rain–cathedral), but in others, they were syllables paired with word, syllables paired with pictures, and words paired with pictures. Calkins then gave the participant the first item from a pair and asked to recall the second item in the association. For example, if the participant had studied a word-word paired associate, such as captain–carbon, she presented the first word in a word-word pair (captain), and the participant would have to respond with the target, that is, the second word from the pair (carbon).

Shortly after Calkins published her study, the behaviorist tradition would become dominant in American psychology. The behaviorists did not think memory was an appropriate topic of research, as memory is not a directly observable behavior. However, Calkins's methodology was easily carried over into this way of thinking, and thus learning research in this time period heavily relied on her methodology. Calkins's stimulus-response approach to memory preserved the importance of memory research in this period.

Calkins also made some significant discoveries concerning the nature of human memory. First, Calkins found that the greater the overlap between meaning in cue-target pairs, the easier it was for the participant to learn and retain the information. Prior familiarity with the cue-target pairs also helped learning. Thus, for example, it was easier for her American students to learn English-French word pairs than it was to learn English-Turkish word pairs because the French words were more familiar to her students, even if they did not know the meanings prior to the study (see Bower, 2000).

Second, in her investigations of short-term memory, Calkins also discovered the recency effect—that is, in immediate recall (that is, when the test occurs right after learning), items that were most recently learned are remembered better than items from the middle of the list. For more on the life of Mary Calkins, go to www.sagepub.com/schwartz.³
Behaviorism

In the early 20th century, behaviorism was the predominant approach in American experimental psychology. Behaviorism took a somewhat paradoxical approach to learning and memory. Learning was a suitable topic of research because it was directly observable. However, memory, or the internal contents or stored information, is not directly observable. Thus, behaviorism focused on learning but deliberately ignored memory. Starting with the work of J. B. Watson (1913), behaviorism stipulated that psychology should focus only on observable verifiable behavior. Behaviorism emphasized the nature of environmental stimuli and their influence on the observable behavior of humans and other animals. Behaviorists did not consider the concepts of thought, mind, images, emotions, and memory to be the appropriate issues of psychological science because they could not be directly observed.

Although contemporary cognitive psychologists no longer agree with these assumptions, behaviorism made important contributions to the study of learning, particularly in the areas of classical conditioning and operant conditioning. Classical conditioning occurs when a neutral stimulus is continually presented along with a stimulus that has a particular association. After enough repetition, the neutral stimulus acquires some of the characteristics of the other stimulus. For example, in many people, riding a roller coaster may trigger a nauseous response. Initially, the smell of diesel may be a neutral stimulus. But if a person rides enough diesel-powered rides, he or she may get nauseous at the smell of diesel alone, even if there is no dizzying ride in sight. Operant conditioning means that an animal learns to respond in a particular way because whenever the animal does respond in that way, it receives reinforcement or avoids punishment. Thus, a young child who makes requests without using the word please may have a request refused, but when he or she makes requests using the word please, the requests are granted. Both the punishment and the reinforcement will increase the likelihood that the child will utter “please” when making a request.

These learning methods appear to be widespread across animals from the most simple to the most complex, including humans. Because of its commonness across animals, behaviorists often speculated that all learning was based on classical and operant conditioning. Indeed, with respect to human verbal memory, an attempt was made to understand...
memory in terms of these principles; it was labeled S-R psychology for stimulus-response (Bowers, 2000). By the 1960s, these S-R psychologists studying verbal learning started switching to cognitive models of memory. There were simply too many phenomena for which classical and operant conditioning were not enough to explain and that required thinking about internal memory states to predict.

**Frederic Bartlett**

Frederic Bartlett was a British psychologist who rejected the approach of behaviorism as well as the methodology of Ebbinghaus. In 1932, he published an important book titled *Remembering: A Study in Experimental and Social Psychology* (Bartlett, 1932). In contrast to Ebbinghaus, who emphasized “pure” memory uninfluenced by meaning, Bartlett considered the issue of meaning to be inseparable from the nature of human memory. As such, his studies focused on meaningful stimuli, like stories, and how expectations could subtly distort people’s memory of these stories. For example, he had Cambridge University students read Native American folktales. When the English students retold the stories, they were biased in their retelling, in ways that revealed their particular culture. Inexplicable and magical aspects of the story tended to be replaced by more rational versions of the stories. Bartlett greatly influenced the emphasis on real-world memory and everyday issues that grew in memory research in the 1980s and continue today (Cohen, 1996). Bartlett’s influence has also been felt in the recent interest in memory accuracy and its converse, false memory. For more information on Sir Frederic Bartlett, go to www.sagepub.com/schwartz.

**Endel Tulving**

Tulving is a Canadian memory researcher, born in Estonia, who is now in his 80s and still very active in memory research (see Figure 1.2). Tulving served as an army translator for the U.S. and Canadian armies during World War II in Germany before immigrating to Canada. There, he attended the University of Toronto, and later, as a graduate student, he went to Harvard University. Eventually, he became a distinguished professor of psychology at the University of Toronto. Perhaps no scientist ever has made more meaningful and varied contributions to the science of memory than has Dr. Tulving. He has made innumerable contributions to the scientific study of memory over the years, starting in the 1950s and continuing to the present. Taking first the perspective of cognitive psychology and later cognitive neuroscience, Tulving has introduced to the field many of the theoretical ideas
that all memory researchers now rely on. He is credited with developing the ideas behind encoding specificity (the idea that retrieval is better when it occurs in situations that match the conditions under which the memory was encoded). He is credited with the idea that long-term memory involves multiple systems. When he introduced the idea of multiple systems, it was roundly criticized. But today, it is universally accepted, in one form or another, by memory scientists. Tulving (1972) initially labeled these systems episodic memory (memory for personal events from one’s life) and semantic memory (memory for facts). The theory has evolved considerably over the years, but the semantic/episodic distinction has stood the test of many empirical studies (Tulving, 1983, 1993, 2002). Both episodic memory and semantic memory are considered long-term memory systems, but they differ in the content of their representations, that is, what they are about. He also pioneered the study of the experience of memory, from how memories “feel” to us to the ways in which we monitor and control our own memory. In recent years, he has also become a leader in the field of cognitive neuroscience, focusing on the neural underpinnings of human memory. In this area, he has been instrumental in demonstrating the areas of the brain associated with remembering our personal past and exploring differences between the left and the right hemispheres. For more on the life of Endel Tulving, go to www.sagepub.com/schwartz.5

Cognitive Psychology

By the 1960s, memory scientists started finding the behaviorist models unable to explain many of the phenomena that they were starting to study, including why different variables affected short-term and long-term memory (L. R. Peterson & Peterson, 1959). Thus, memory scientists started switching from S-R models to models emanating from the new science of cognitive psychology, which emphasized the concepts of mind and internal representation of memories (Neisser, 1967). This change involved two big features. First, cognitive psychology reopened the “black box” and allowed mental processes and “mind” to become appropriate topics of study. Second, it postulated that mental states are causal, not simply the by-products of behavior. Cognitive psychology proved useful in addressing issues of language, attention, and decision making, as well as memory, and continues to be a dominant force in psychological theory. For example, behaviorists were reluctant to address the issue of representation (or storage) in memory because it is a hidden process not directly observable through behavior. Theory in cognitive psychology has led to a variety of ways of addressing the issue of representation and studying it through careful experimentation.

At the core of theory in early cognitive psychology was the idea of the flow of information. For this reason, it often relied on an analogy to the computer in which information also moves and is transformed over time. For example, the study of encoding became the study of how information is transferred from short-term memory to long-term memory and how this process unfolds over time. The idea of the flow of information remains controversial. Many modern cognitive psychologists disagree with this view because the brain is a remarkably parallel device, doing many things at once as opposed to doing one thing at a time, albeit very fast.
Cognitive Neuroscience

**Cognitive neuroscience** is the study of the role of the brain in producing cognition. Traditionally, the correlation between brain processes and cognitive processes was studied by examining the cognitive deficits seen in patients with brain damage. Most recently, advances in neuroimaging techniques have led to tremendous gains in our knowledge of the biological processes involved in memory. Neuroimaging allows us to observe the intact living brain as it learns, remembers, communicates, and contemplates. The past 10 years of neuroimaging research have provided great progress in understanding both the workings of the brain and why certain memory processes are the way they are.

For example, Martin Conway and his colleagues (Conway, Pleydell-Pearce, Whitecross, & Sharpe, 2003) conducted a study in which they examined the relation between regions within the brain and retrieval of autobiographical events. Think about an event that happened recently to you, such as visiting the zoo. What areas of the brain become active as you contemplate your memory of the trip? This is what Conway and his colleagues were interested in.

Conway et al. (2003) studied this phenomenon by asking people to remember particular events while imaging equipment was monitoring their brains. To be more specific, the participants thought of the first personal memory that a particular word evoked. The cue word was provided to the participants by the researchers. Thus, in response to the word *rock*, an individual might remember his recent visit to the local rock-climbing gym and remember his satisfaction at completing a particularly difficult route. In response to the word *church*, a participant might remember her sister’s wedding ceremony and how beautiful the church looked that day. Using a neuroimaging technique called EEG (electroencephalography), Conway et al. followed the path of memory retrieval as it played out in the brain.

Conway et al. (2003) found that immediately after the presentation of the word, areas in the prefrontal cortex (the very front of the brain, just under your forehead) of the brain became active. Conway et al. interpreted this to indicate that this was the brain going into “retrieval mode.” At just about the point people indicated that they “had the memory,” areas in the occipital lobe (in the back of the brain; associated with vision) became active. That is, the visual imagery associated with a particular memory was apparent in the EEG patterns. At the same time, areas in the hippocampus (associated with memory encoding and retrieval) also became active. Thus, Conway et al. were able to map out both in time and space the pattern of retrieval in the brain and correlate it with how people remember autobiographical events (see Figure 1.3). Moreover, Conway et al. also compared real memories with imagined events. The imagined events never occurred, but the participants were asked to produce plausible imagined events. The imagined events had much more activation in the prefrontal lobes than did the real events and less activation in visual areas of the brain. Thus, it may even be possible to distinguish real and false memories from their signature patterns during neuroimaging. The integration of cognitive memory theory with neuroscience is revolutionizing the way we think about memory.
Slow potentials observed when experienced and imagined memories were held in mind over a 7.5s period. Electrolytes are displayed. Note that experienced memories are associated with greater posterior activity.

SOURCE: Conway et al. (2003).
METHODS OF STUDYING MEMORY

We all feel familiar with the workings of our own memories. One individual might report that she never remembers her family member’s birthdays. Another individual might tell you that he is not good at remembering faces. Yet, a third will tell you that she has “photographic memory” and can simply look at a page on a textbook and recite all the information on it from memory (this is typically illusory, but more on that in Chapter 5). As memory scientists, however, we cannot simply rely on people’s stories and anecdotes. Instead, we conduct experiments, which measure memory abilities under different conditions. We test to see if all those who claim to have photographic memories really can remember what is on a page of text after one or more casual glances. We test to see how good people are, in general, at recognizing faces and then can objectively tell your friend whether he is indeed above or below the average in remembering faces. In short, to study memory objectively, we must apply the scientific method. By applying the scientific method, we can make generalizations about how memory works in general in human beings and also get reasonable approximations to the extent to which there are measurable individual differences. The key to this enterprise is the experiment.

An experiment is set of observations that occur under controlled circumstances determined by the experimenter. The controlled circumstances mean that the researcher strives to maintain a situation in which he or she has control over what a subject sees, hears, or can potentially remember. The control allows the researcher to focus on one select issue (say, distributed practice vs. massed practice) at a time. By keeping other conditions constant, the researcher can determine if distributed practice is truly better than massed practice.

The experimenter does this by looking at the effects of independent variables on dependent variables. **Independent variables** are the factors that the experimenter manipulates among different conditions. For example, to use a simplified hypothetical example, if an experimenter is interested in whether Starbucks’s coffee can improve memory, he or she can manipulate the amount of coffee given to different groups of participants. Thus, the amount of coffee consumed is the independent variable. Each group receives the same list of words to remember. Thus, one group of people might not get any coffee in advance of studying the list of words. This group is called the control group. A second group might get one cup of coffee in advance of studying the list of words. And a third group might get four cups of coffee in advance of studying the list of words. The second and third groups are considered the experimental groups and are compared to each other and to the control group. Another way of saying this is that there is an independent variable (amount of coffee consumed) with three levels (zero cups, one cup, and four cups). Some time after study, we then test the people to see how much they can remember from the list.
**Dependent variables** are the observations that we measure or record in response to the independent variable. In the Starbuck’s experiment, the dependent variable is the amount of words recalled from the study list by the participants. As memory researchers, we are interested in the effects of the independent variable (amount of coffee consumed) on the dependent variable (amount of words remembered). So, we measure the amount of words remembered for each participant in each condition. We can then statistically compare the outcomes in each condition. The statistical comparison can then inform us if Starbuck’s coffee does help us remember words on lists and if too much coffee (i.e., four cups) just makes us too jittery to concentrate on anything (see Figure 1.4). In memory science, we will see a few dependent variables used extensively in the work described in this book. These dependent variables include recall, recognition, and a variety of judgments.

A number of features must be included in an experiment to make it a good scientific study. First, **random assignment** means that any particular person is equally likely to be assigned to any of the conditions. Usually, a random-number generator assigns any individual to one of the possible groups. In the coffee experiment, you would not want to put the people who you know are good at memory in the four-cup condition, as their propensity to remember well would bias the results. You want a representative sample of people

![Figure 1.4 Graph of memory as a function of caffeine consumed.](image)

This graph shows a potential hypothetical outcome. Small amounts of caffeine lead to boosts in memory, but a larger amount hurts memory. In fact, research shows that caffeine can hurt memory even at smaller amounts. The y-axis is the number of words recalled.
who are good and poor at memory in each condition. The best way to do this is to assign each person randomly to one of the conditions. Second, the participants should not know what you expect to find in the experiment until after the experiment is over. Even the most honest participants may slightly alter their concentration or attention to satisfy (or perhaps disrupt the experiment) if they know what the experimenter wants to find. Third, as best as possible, the person actually running the experiment should not know what condition each participant is in. So the person actually administering the memory test should not know if an individual had zero, one, or four cups of coffee, as this too might introduce subtle bias into the experiment. These last two concerns make up what is called a double-blind procedure, that is, neither the tester nor the participant should know what condition that person is in.

When these conditions are met, our experiment will test only the independent variable or variables that we are interested in studying. We can be sure that other extraneous factors have been controlled for by randomizing the assignment of participant to condition and by keeping both the participants and the experimenters unaware of what condition they are in. This allows us to be confident that any differences we get between conditions are a function of the independent variable. Thus, we can safely conclude what are the effects of caffeine on the learning of the list.

In memory research, it is also crucial to have good dependent measures. Because we are interested in memory, we need good tests of memory. These tests are the dependent variables in the experiments on memory. Thus, scientists have developed a large set of memory measures so that researchers can choose the right dependent variable for their experiment. The next section will review these common measures, which we will see throughout the book.

**MEMORY MEASURES**

**Recall**

Recall means that a person must generate the target memory. That is, **recall** is the producing of a memory or a part of one that was not already presented. For recall, a person must speak or write the remembered items without seeing them in advance. In some cases, a recall test might involve reenacting a physical event as well. Recall can be free recall, in which you are given a global cue to remember a particular memory or set of memories. “Tell me about your childhood,” “what were all the words on the study list,” “write two paragraphs about the fall of the Peloponnesian war,” and “describe everything you saw at the scene of the crime” are examples of free recall. The cue “tell me about your childhood” provides no information about one’s childhood.

**Random assignment**: any particular participant is equally likely to be assigned to any of the conditions.

**Double-blind procedure**: neither the tester nor the participant should know what condition that participant is in.
Thus, all the information recalled is freely selected by the rememberer. In memory experiments, free recall is more likely to be of the “write down all the words from the list” variety. Cued recall occurs when you are given a specific cue to remember a specific memory. Cued recall includes questions like, “What is your middle initial?” “What word went with pasture on the study list?” “In what year was the Greek philosopher Aristotle born?” and “What color car were the bank robbers driving?”

Cued recall is also a common technique in memory experiments. It is useful in looking at association in memory, that is, the connection between two ideas of two memories. Thus, for a student learning French, a person must associate the English and the French words, as in dog–chien. In a cued recall test, you might receive the English word (dog) and be asked to recall the French word.

**Recognition**

*Recognition* means matching one’s memory to a presented choice. Rather than having to produce the item itself, the person must match what is stored in the memory with what he or she sees in the list. Recognition can be old/new recognition, in which the person has to decide if an item was on the study list. If the participants saw the word *pasture* on the study list, they would need to indicate that by saying “old,” whereas if the participants had not seen the word, they would indicate that by saying “new.” Recognition can also be forced-choice recognition, also known as multiple-choice recognition. In this case, a question is asked with a series of possible answers. Using the earlier examples, we could ask a recognition question such as, “In what year was Aristotle born? (a) 502 CE, (b) 5 CE, (c) 384 BCE, (d) 672 BCE. (The correct answer is 384 BCE.) A police lineup is technically a recognition test as the witness can see all of the possible suspects. Most police lineups, however, are not forced. The witness can say “not there” if none of the suspects match his or her memory. The key difference between recall and recognition is that in recall, the person must generate the memory, whereas in recognition, the person must match what is in his or her memory with what he or she sees in front.

**Implicit Memory Tests**

*Implicit memory tests* are tests that draw on the nonconscious aspects of memory. That is, memory is tested without the person being conscious of the fact that his or her memory is being assessed. In some cases, the participant may not have conscious access to the memory at all, although this is not required for the task to be classified as implicit.

To give an example, something as simple as a spelling test can be used as an implicit memory test. Eich (1984) presented two streams of stimuli, one to each ear of his participants. The participants were directed to attend to one of the two stimuli and to ignore the other. Decades of research on attention demonstrate that people are very good at focusing...
on one message and ignoring the other. In Eich’s study, in a test of free recall, the participants remembered very little to nothing at all of the unattended stimuli. However, Eich found that even though they could not consciously recall the items presented to the unattended ear, there must have been some memory of them because it biased their spelling of homophones (words with different meanings that sound the same but are spelled differently). Some of the items presented to the ignored ear were sentences like, “The men took photographs of the grizzly bear,” and “The fencers flashed their swords of cold steel at each other.” During the spelling test, participants were read aloud words to spell, including *bare/bear* and *steal/steel*. No instructions were given as to how to choose which of two spellings they should use. Participants who had heard these words were more likely to spell them according to the given context, even though they could not consciously remember having heard the words. That is, relative to control participants who had not heard the words being presented to the unattended ear, those who had were more likely to spell *steal/steel* as *steel* and *bear/bare* as *bear*. This increase (or decrease) in performance based on some prior processing is known as *priming* (see Jacoby, 1991).

### Source Judgments

**Source judgments** are our attributions of where or from whom we learned something. Thus, I know that the first European settlers introduced rabbits to Australia. However, I cannot recall who told me this, where I read it, or when or where I may have seen this on a nature television show. In many cases, remembering the source is vital to your appraisal of the memory. We must remember where or from whom we heard the information. Consider a situation in which, while gossiping with a friend, you mention that the actress Cameron Diaz is having a baby. Your friend asks, “Where did you hear that?” In such gossip, the source of a memory is important. If you read it in a tabloid newspaper, such as the *National Enquirer*, it may be of dubious validity. However, if you saw it on CNN, it is more likely to be true (but no less any of your business). Source judgments are decisions researchers ask people to make regarding from whom they heard information (Foley & Foley, 2007). In some experiments, for example, two individuals, one male and one female, may read a list of words. The two readers alternate, each one reading one word, and then the other one reads a word. Later, participants must recall not only the words but also which speaker said which one. Related to source judgments is the concept of *reality monitoring*. Reality monitoring refers to our ability to distinguish whether our memory is of a real or an imagined event. Each of us may have memories of fantasies (being elected president, for example), but it is important to recognize these memories as being internally generated rather than based on real events.
Metamemory Judgments

**Metamemory** means our knowledge and awareness of our own memory processes. Metamemory judgments are the ratings or decisions we make concerning what we know about our memory processes. Metamemory includes our knowledge of our own strengths and weaknesses about our memory (when we say, “I am good at remembering faces,” we are making a metamemory statement). A tip-of-the-tongue state is also a metamemory judgment; we are confident that an unrecalled word will be recalled (Schwartz, 2002). Usually, in memory experiments, the metamemory judgments refer to whether we think we can learn or retrieve a particular item. Judgments of learning are predictions of the likelihood of remembering an item that we make as we study the items. We can then ascertain if these judgments are accurate by later correlating them with actual memory performance. Other metamemory judgments include ease-of-learning judgments, confidence judgments, feelings of knowing, and tip-of-the-tongue states. Metamemory will be covered extensively in Chapter 9.

These five categories (recall, recognition, implicit memory tests, source judgments, metamemory judgments) make up the vast majority of measures that memory scientists use to study human memory. Almost every behavioral experiment that we will cover in this book makes use of one of these five techniques. So make sure you know what they are and what they mean now! The next three methods are drawn from the neuroscience/neuroimaging perspective on memory research.

Neuropsychology

The study of patients with brain damage has a long and distinguished history (Feinberg & Farah, 2000). Indeed, ancient Egyptian doctors noted that blows to specific areas of the head resulted in characteristic damage. Nowadays, the goal of neuropsychological research is to correlate the specific area of brain damage with the cognitive or behavioral deficits seen in a particular patient. You can see the change in language behaviors based on damage to an area of the brain called Broca’s area (go to www.sagepub.com/schwartz). For many patients, the damage is too wide, too diffuse, or too minor to be of interest to neuropsychologists. But if the damage is relatively restricted, whatever behavioral changes occur in a patient can be linked to that area of the brain. For example, a patient who has damage to the hippocampus (a small part of the brain in the limbic system) will show deficits in learning new information but not in retrieving information that is already well learned. Thus, we can conclude that the hippocampus is involved in the encoding of new events. Another patient might have damage restricted to areas of the right frontal lobe, which will result in difficulties in remembering the source of information. In this way, by probing the nature of brain damage, we can develop a model of the relation between particular brain region and memory function. Unfortunately, strokes, tumors, auto accidents, and war injuries will be with us for the foreseeable future.
Thus, neuropsychology will continue to have a role in both learning from these patients and, it is hoped, learning to help these people recover.

Animal Models

Many animals, including most mammals and birds, have complex brains. Many of the structures involved in memory are common across these animals. For example, the hippocampus is involved in memory in both mammals and birds, even though their common ancestor lived long before the dinosaurs went extinct. Animals can be used in simple behavioral experiment because, in general, their memory systems are less complex than ours. In the past, animals, particularly rats and rhesus monkeys, have been used for single-cell recording. In single-cell recording, electrodes are inserted into individual neurons in the animal’s brain. Then researchers can determine what kinds of stimuli elicit responses in that cell. Animals have also been used for lesion studies, in which parts of their brain are surgically removed. Because both of these methods involve invasive and potentially painful procedures, they are now used only for medically critical experiments.

Neuroimaging

Neuroimaging techniques are advanced technologies that allow us to visually examine intact human brains. This area has seen marked growth in recent years and will be one of the issues that we focus on in Chapter 2. These techniques allow scientists to correlate behavior with function in the brain in normal active brains. Indeed, modern neuroimaging techniques allow us to trace the flow of information in the brain as individual people think. As of yet, they cannot tell what a person is thinking, but when a person reports what he or she is thinking, there seem to be reliable correlations between that person’s reports and particular parts of the brain. Neuroimaging techniques have been used to investigate memory, perception, language, and emotion. Two goals of neuroimaging are to determine where things happen in the brain. For this, neuroimaging can develop detailed spatial maps of the brain and which areas are active during which cognitive task. Another goal is to determine the flow of activity in the brain over time. For this, neuroimaging must be able to take quick successive pictures of the brain in order to determine the time course of processes in the brain. It is important to note that no serious scholar of memory would argue that the brain is not responsible for cognitive processes. Therefore, for some cognitive psychologists, knowing where in the brain particular processes operate is less interesting than why they operate the way they do.

There are three major techniques used in neuroimaging today.

1. EEG (electroencephalography): measures the electrical output of the brain. Electrodes are placed on various places on the scalp, sometimes as many as 64 electrodes. Each electrode can then pick up a signal from the total electrical output. However, areas
of the brain that are active will generate more electric output in total than those that do not. Thus, we can see where things are happening in the brain by comparing these outputs. Because the electrodes pick up a continuous electric signal, measurements can be made very quickly, in fact, on the order of every millisecond (1/1,000th of a second). Therefore, EEG provides an excellent way of measuring the changes that happen in the brain as a person engages in a memory task.

2. **PET (positron emission tomography).** In PET, a small radioactive tracer is injected into a person’s bloodstream. The radioactive tracer travels in the bloodstream to all areas of the body, including the brain. Areas of the brain that are active will require more blood than areas that are resting. This is the fundamental assumption of neuroimaging—that blood flows to areas of the brain that are active. Therefore, more radioactivity will be drawn to active regions of the brain. A complex X-ray-like camera measures the emission of the radioactivity and determines where it is coming from in the brain. From this, researchers can determine what areas of the brain are active during different memory processes. PET is very good at making spatial maps of the brain and pinpointing where in the brain activity is taking place. However, successive images can be made only every 30 seconds, so it is not helpful in determining the flow of information in the brain.

3. MRI and **fMRI** (magnetic resonance imagery and functional magnetic resonance imagery). In this technique, people are put in large magnetic fields, which align the molecules in the brain. Then as blood flows into areas of the brain, the molecules’ organization is disrupted. A specialized camera detects this disruption. In the fMRI technique, it is the oxygen molecules in the blood that are traced. This allows the technique to measure which areas of the brain are more active during any particular cognitive task. Because fMRI can take another picture every half of a second, the technique permits the researcher to determine both where in the brain a particular memory function is taking place and how it changes over time. Thus, fMRI has the advantage of both EEG and PET, although it is still slower than EEG. It is also safer than PET because no radioactivity is involved. Its only current drawback is its expense and that you cannot place electronic devices such as computers into the magnetic field without totally destroying the electronic device. For a video clip showing fMRI, go to www.sagepub.com/schwartz.

Throughout the book, we will be discussing research generated from each of these three neuroimaging techniques. The fMRI technique is currently the state of the art in neuroimaging. It is providing insight into the workings of the brain not just for memory but almost all areas of human thinking and emotion (see Figure 1.5).
Figure 1.5  Person having MRI. Despite appearances, having an MRI is painless. Without introducing any harm, the MRI can produce a detailed image of the intact human brain.

MEMORY IMPROVEMENT

One of the themes of this book is that you can use the principles advanced in this textbook to improve your own ability to learn and remember. Memory science has found a great many ways in which learning efficiency can be improved and memory can be enhanced. However, the first point to be made is that there is no memory magic bullet—no one sentence that I can write that will transform you, the reader, into a mnemonic marvel. Nor is there a pill that your doctor can prescribe that will radically improve your ability to remember information. To state bluntly a point that will be repeated throughout the book: Memory improvement is hard work! Yet, the hard work can be directed in thoughtful and informed ways in order to be more efficient. Memory science knows a lot about what makes for good learning and good remembering. The informed student can apply much of this information to his or her schoolwork or other aspects of daily life that require remembering.

When discussing memory improvement, it is important to begin the discussion of types of memory. Chapter 3 will outline the current theories concerning how many different memory systems human beings actually have. Although there is some debate as to exactly
where to draw the lines between one memory system and another, it is now abundantly clear that not all memory is alike. Indeed, the research suggests that there are a number of systems of memory with different neurological underpinnings (Schacter, 2007). For example, the learning and remembering required to play the violin is very different from the learning and remembering required to master the rules of spoken German (or any other language). The rules that govern remembering the individual events from our lives are quite different from the learning and remembering of facts that we must learn in school. Thus, the principles that govern memory improvement are going to differ between one domain and another. Use of visual imagery mnemonics, for example, is useful for mastering new-language vocabulary (Thomas & Wang, 1996) but of no use in learning to play a new musical instrument. Similarly, using linkword mnemonics to help learn name-face associations is useful, but linkword mnemonics will not help you remember the name of your kindergarten teacher when somebody asks you. Having said that, a number of principles do apply across a wide domain of memory systems. The spacing effect, described in the section on Ebbinghaus, is one such example. Spaced rehearsal is helpful for remembering facts about the world, learning a skilled task such as typing or playing a musical instrument, and remembering landmark events from one’s life.

Mnemonic Improvement Tip 1.3

There is no magic bullet for memory. Good memory requires hard work.

While students are usually chiefly concerned about ways in which they can improve their ability to remember raw information, older adults are often more concerned about the failings of another aspect of memory, known as prospective memory. **Prospective memory** is memory for the things we need to do in the future. This is not some weird science fiction–type thing. It refers to the fact that we need to remember our future plans. Parents have to remember to pick up their kids at school, employees have to remember to pick up the mail from the mailroom, chefs have to remember exactly what time to take the soufflé out of the oven, and husbands must remember to put the garbage out on the curb. And perhaps most important, individuals requiring medication must remember to take their medication at the prescribed time of day. In other words, prospective memory is about remembering intentions (McDaniel & Einstein, 2007). McDaniel and Einstein made a series of recommendations as to how we can improve our prospective memory. However, most of their recommendations involve the extensive use of external cues. That is, if you need to remember to pick up your kids at school (perhaps normally your spouse’s task), you can carry a photograph around of them. Place it (in your pocket) where you will keep coming across it. The constant reminder will help you to remember your intention even if you are a chef and busy with your soufflé. Similarly, if you have
to remember to return a particular book to the library, place it by your car keys the night before. When you look for your keys to drive to school, you will also find the book you need to return to the library. Once you are in your car, place it in the passenger seat, so you see it and won’t drive to school or work without stopping at the library (for further information on this topic, go to www.sagepub.com/schwartz).  

We can improve our memories. In this book, I hope to offer a number of ways in which memory science has shown that memories can be improved. However, I will reiterate the following point: Memory improvement is an active process. It doesn’t just happen; we have to work to make it happen. Indeed, both of the recommendations made in this chapter require active memory improvement. We must think about how to distribute our learning; it requires a little planning. And taking advantage of external cues also requires us to work a little. We have to think about our routines and use them to our advantage. Last, in this chapter, I will present four themes, which will be returned to repeatedly throughout the book. Each theme represents an important concept in memory theory and practice (for further information on this topic, go to www.sagepub.com/schwartz).  

Mnemonic Improvement Tip 1.4

External cues can help. But external cues require action. You must place them in your environment.

THEMES FOR THE BOOK

1. Learning and remembering are active processes. Human beings are learning animals. Learning is what we do best. Human beings can learn to knit sweaters in intricate patterns, and we can learn to negotiate small kayaks down ferocious whitewater that would drown the untrained person. Some human beings memorize the Bible or the Koran, whereas others can tell you the complex ingredients to a crème brûlée. But little if any of this learning happens passively. The person who learns and remembers best is the person who seeks out opportunities to learn, who rehearses the information, and who teaches to others. Throughout this book, I will make note of how the active learner who employs strategies, relates information to himself or herself, organizes information, and employs metamemory strategies winds up learning a lot more than those who do not.

2. Learning and remembering have a biological/neurological basis. Our brains are our biological organ of learning and remembering. In the past two decades, with the advent of neuroimaging, there has been tremendous growth in our understanding of how the brain works, particularly with respect to learning and memory. Our understanding of behavior, memory, and cognition has guided much of this neuroscience research, and in turn, neuroscience is now guiding the questions we ask of our memory systems. Chapter 2 will provide an overview of what we know of the neurological basis of memory,
and then each chapter will discuss the specifics of a particular aspect of memory and how it plays out in the brain.

3. Memory has multiple components, which act in different ways. We have many different kinds of memory. We have memory for the individual events from our lives, for the words of our native languages, for the geography of our home and surrounding areas, and for the music we love. We hold some memories, like the phone number of the pizza place as we dial it, for very short periods of time, whereas other memories such as an individual’s wedding ceremony or the time you hit a home run in little league may last a lifetime. We have several different neurocognitive systems to handle these different kinds of memory. Chapters 3 and 4 will explore the nature of these memory systems.

4. Learning and remembering can be improved. By applying many of the facts, theories, and ideas of memory science, we can improve our ability to learn and remember. Many of these are ways of managing our existing resources and efficiently using our time. We can apply a number of principles consciously to both our efforts to learn information and our efforts to remember information. In each chapter, there will be memory hints, which are based on the research discussed. Each hint will provide a method whereby you can improve some aspect of learning and remembering. And then, in Chapter 9, an entire chapter will be spent on the topic.

SUMMARY

Understanding the science and practice of memory is the overarching goal of this book. Memory is an essential component of our cognitive systems and indeed our sense of who we are. This book addresses the science of memory, what we know from both the point of view of cognitive psychology and from cognitive neuroscience. In both domains, established methodologies allow us to analyze and think about memory research. From this research, we can draw practical applications that will allow each of us to improve and make more efficient our own learning. We also reviewed the history of the field, starting with the seminal work of Hermann Ebbinghaus. Ebbinghaus established a number of key findings, including aspects that benefit memory performance. Following Ebbinghaus, Mary Calkins, Frederic Bartlett, and Endel Tulving defined the future of memory along with bigger schools of thought, such as behaviorism, cognitive psychology, and cognitive neuroscience. This chapter also reviewed the fundamental techniques used to study memory from behavioral measures such as recall, recognition, and metamemory judgments to neuroscience methods, such as fMRI and PET. Four overarching themes were introduced, focusing on the active nature of learning and remembering, its status as a biological process, that memory is composed of multiple systems, and that we can use principles of learning and remembering to improve our individual ability to learn and remember. With this in mind, we will begin our exploration of the fascinating world of human memory.
# KEY TERMS

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<td>Spacing effect</td>
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<td>Recency effect</td>
<td>Double-blind procedure</td>
<td>Prospective memory</td>
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# REVIEW QUESTIONS

1. Who was Hermann Ebbinghaus, and what were his important contributions to memory science?
2. How can the spacing effect be used to improve memory?
3. How did the contributions to modern memory science of behaviorism and cognitive psychology differ?
4. What are the key components of a memory experiment?
5. What is the difference between recall and recognition?
6. What are source judgments? What are metamemory judgments?
7. How does studying neuropsychological patients aid in understanding the nature of memory and the brain?
8. What are the three techniques of neuroimaging? What are the advantages and disadvantages of each?
9. What is prospective memory?
10. What are the four themes of the book? Why are they important?

# ONLINE RESOURCES

1. For a good website on the general philosophy of science, go to http://teacher.pas.rochester.edu/phy_labs/appendixe/appendixe.html.
2. For Hermann Ebbinghaus’s book, see http://psychclassics.yorku.ca/Ebbinghaus.

3. For more on Mary Calkins, go to http://www.webster.edu/~woolfm/marycalkins.html.

4. For more on Frederic Bartlett, go to http://www.ppsis.cam.ac.uk/bartlett.


6. See a patient with Broca’s aphasia at http://www.youtube.com/watch?v=f2iIMeBmNPM.

7. For a video depicting fMRI, go to http://www.youtube.com/watch?v=PYg09mPA8fA.

8. For the latest on memory research, go to http://www.memoryarena.com/resources.

9. For the latest research on applications of memory, go to http://www.sarmac.org/index.htm.

Go to www.sagepub.com/schwartz for additional exercises and study resources. Select Chapter 1, Introduction to the Study of Memory for chapter-specific resources.