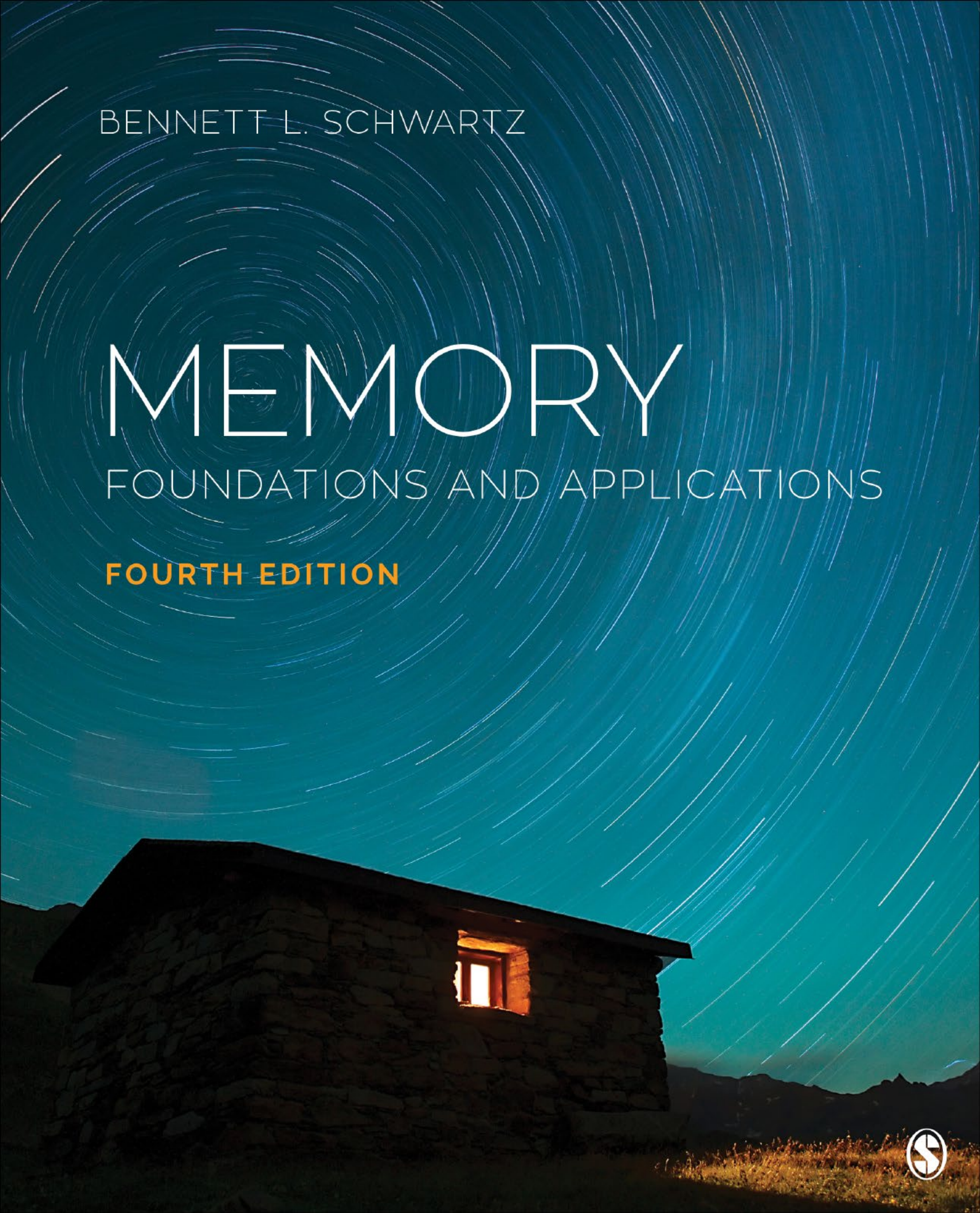
BENNETT L. SCHWARTZ

MEMORY

FOUNDATIONS AND APPLICATIONS

FOURTH EDITION



Memory

Fourth Edition

This book is dedicated to the memory of my mother and father,
Carol Halpert Schwartz and Foster Schwartz.

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Bennett L. Schwartz

Florida International University

SAGE

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PREFACE

It is hard to imagine an aspect of psychology more fundamental than memory. Without a functioning memory, all other cognitive functions—perception, learning, problem-solving, and language—would be impossible. Other aspects of life would also be difficult. Emotion is informed and influenced by memory. Decision-making, from small to big decisions, is informed by memory. Many daily activities, from walking to turning on our phones, require learning, which requires functional memory systems. Without intact memory, social interactions such as play, relationships, and work would be chaotic at best. For this reason, the study of memory has been important to psychologists from the very beginnings of psychology.

When I teach memory, students most commonly have the same question: How can I improve my own memory? However, memory textbooks seldom address this topic. Students learn about memory models, theories, a great many experiments, much about neuroscience, and the brain. These are all important if one is to understand how memory works, and these issues are well covered in this book. But *Memory: Foundations and Applications, 4th Edition* is also designed to instruct students to apply these concepts to their everyday life and use them to improve their individual ability to learn and remember. The fourth edition includes an extended discussion of retrieval practice, a discussion of the benefits of distributed learning, a warning about the hazards of distraction, and a warning about the nature of stability bias, all of which can be used by students to improve the efficiency of their learning.

The classroom itself has changed drastically in the past few years of higher education. Classes have companion websites, and in many cases, entire classes are online—students may never see their professors. College students have been downloading information from the Internet since they were in elementary school. I want *Memory* to capitalize on these sources of information. Thus, the book contains references and links to websites where students can learn more about a particular topic or a particular individual's research. I believe that this approach will be conducive to the way modern students have grown accustomed to learning. On the other hand, *Memory* provides depth into the science and methodology of memory that may not be easily available from Internet sources. In the end, in many classes, there is still a professor in front of a classroom and a student reading a textbook. I wanted a textbook that provided depth and created interest in the field of memory—that is, a textbook that students would want to read. The balance between depth of understanding and ease of access is difficult in a world of super-information, but that is what I've strived for.

This book emphasizes the science of memory. It describes experiments, patients with memory disorders, the areas of the brain involved in memory, and the cognitive theory that links this research together. I have tried to write this book with students in mind—their concerns, priorities, interests, and curiosity. I hope at the same time that this book emphasizes the science of memory, that it also tells a story about our search to understand our own minds and how we can benefit from that understanding.

ORGANIZATION AND CONTENT

Memory is an accessible textbook on memory science presented in clear and understandable language. Starting with the fourth edition, a new organization is being employed. Section 1 includes the first five chapters and is devoted to the theoretical development of ideas in memory research (Memory and Processes of Memory). The second section—Chapters 6 through 9 (Advanced Topics in Memory)—is devoted to advanced and interesting topics in memory research (e.g., prospective memory and metamemory). Finally, the third section—Chapters 10–13 (Applications of Memory Research)—is devoted to application of memory research to a variety of real-world situations. This three-pronged organization will give students a general overview of the basic psychological science of memory, give them some expertise in advanced topics, and then allow them to think about how memory research can benefit society.

I also wish to be integrative in the way content is delivered. Thus, instead of having separate neuroscience sections, each chapter integrates findings from neuroscience. Topics such as the time course of brain activation during autobiographical memory, the regions of the brain involved in encoding, and the regions of the brain involved in monitoring are included in the flow of the chapters rather than in a separate section at the end of each chapter or a separate chapter entirely. Neuroscience is not simply presented as a map as to where memory processes occur but also how the neuroscience data can shape how we construct our theories. *Memory* is unique in its emphasis on applications, in educational situations, police investigations, courtrooms, hospitals, memory clinics, and everyday life.

WHAT'S NEW TO THE FOURTH EDITION

Memory introduces some major changes into the organization from previous editions. These changes reflect current concerns in the field about the emphasis on application of memory research. In the fourth edition there are now chapters dedicated to memory impairment in brain-based disorders (Chapter 10), memory impairment in psychiatric disorders (Chapter 11), applications of memory research to the legal system (Chapter 12), and applications of memory research to improving the efficiency of one's own memory (Chapter 13). These chapters reflect an increased interest in neuroscience as well, as the memory impairment chapters focus on how the brain interacts with disease to create the impairment. They also reflect the growing understanding that all of us can apply principles of memory to improve our own learning. Thus, the fourth edition greatly expands on the importance of applications of our expanding understanding of human memory. Moreover, *Memory* is thoroughly updated with new research findings. The fourth edition now has 161 new references to papers that were not in previous editions. The fourth edition is now the most up-to-date textbook in the field. Some of the pivotal changes from the third edition include a complete chapter devoted to how memory science is relevant to the legal system, a complete chapter on memory issues in psychiatric disorders, a reorganized chapter on memory development, and an enlarged section on prospective memory now combined with the chapter on metamemory. Within chapters that maintain the organization from earlier editions one can find new content that includes an updated section on cognitive maps, on autobiographical memory and emotion, and expanded discussion of the memory component of Alzheimer's disease.

PEDAGOGICAL FEATURES

Each chapter begins with learning objectives, followed by a discussion or exercise that engages the reader with an example or real-life incident that helps illustrate the relevance and importance of each chapter. This opener provides students with an appreciation for the topic and why scientists consider the topic important. Examples and applications of key concepts are integrated throughout the text in a way that students can appreciate the relevance to their lives. Specific pedagogy includes:

1. Learning objectives. Each chapter begins with a list of the objectives for that chapter.
2. Important terms are highlighted in bold. This is useful when students outline their textbooks while studying for exams. It directs them to the parts of the book that are important for studying after the material has been understood.
3. Mnemonic tips. Almost every chapter contains highlighted *mnemonic tips.* These tips state succinctly how a particular concept can be applied to memory improvement. Chapter 13 ends with a list of all the mnemonic hints provided in the textbook.
4. Interim summaries. Every chapter except for Chapters 1 and 13 have interim summaries. These review the main points of the section, emphasize the important points, and provide organization that students can use in study. In the fourth edition, each chapter has one additional interim summary.
5. After each interim summary is a section quiz. These short quizzes allow students to assess their comprehension of the previous section.
6. Key terms. At the end of each chapter, I list the important terms introduced or reviewed in the chapter. Key terms include new definitions, jargon, and concepts, as well as terms that may have been introduced in another chapter but are reviewed here. Students can use the "key terms" section as a way to review. Successfully defining the terms is the first step in mastering the material.
7. Review questions. At the end of each chapter are 10 review questions. Each question prompts the reader toward an understanding of one or more of the important ideas in the chapter. A student who can successfully answer all of the questions at the end of the chapter can be confident that he or she understands the main topics in that chapter.

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—*Bennett L. Schwartz*
September 20, 2019

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Bennett L. Schwartz is Professor of Psychology at Florida International University. A native of Long Island, New York, he earned both his bachelor's degree (1988) and PhD (1993) from Dartmouth College in Hanover, New Hampshire. He then moved to Florida International University in Miami, Florida, where he has been ever since. He does research on metamemory, human memory, and nonhuman primate memory. He has published over 75 journal articles and book chapters in these areas. He has authored, coauthored, or edited 11 books. He is past president of the Southeastern Workers in Memory (2006) and the Southern Society for Philosophy and Psychology (2016), and he is currently editor in chief of *New Ideas in Psychology* and associate editor at *Metacognition and Learning*. He teaches courses in memory, cognitive psychology, and sensation and perception.

MEMORY AND PROCESSES OF MEMORY

SECTION 1

1

INTRODUCTION TO THE STUDY OF MEMORY

LEARNING OBJECTIVES

1. Explain the nature and importance of memory.
2. Describe the history of memory research.
3. Evaluate memory methodology and how it addresses issues of human memory.
4. Demonstrate an understanding of the basic principles of memory efficiency.

Remembering is a part of our every moment. Nearly everything we do throughout the day, including dreaming at night, involves memory. Consider the act of waking up each morning. As the alarm goes off, you must remember whether 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 whether your roommate is in class already or trying to catch up on sleep. If you have a job, do you have any important meetings that you cannot afford to miss? These are just a few of the needs for memory that occur within just a few moments of waking up. As the day proceeds, you have to remember the directions to the university, the material for class that day, how to get from one classroom to another and what rooms classes are in, where your car is parked so you can drive home, and the best route to get home in afternoon traffic. You also 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? 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. Based on these examples, you can see how critical good memory performance is in everyday life.

Memory also forms the basis of our views of ourselves 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 generous act? Do you remember it? When was the last time you volunteered at a soup kitchen? When was the last time you donated to a charity? 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 high 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 first inauguration of President Barack Obama 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 search for the term *memory* on the Internet. I just did and got over 1.67 billion hits. Now some of these deal with computer memory, not human memory, but searching for *human memory* still elicits 555 million hits and *human memory improvement* over 81 million. That is a lot of information, confirming both how important memory is to us and the importance of understanding it. This text should serve to help readers understand both the science of human memory and how that science can be employed to improve the efficiency of our own learning.

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 physical objects, such as a bracelet or ring. Losing these memories, even the bad ones, is seen as devastating. Capitalizing on this fear, movies abound that tell 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 (not 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 of information. Facts, dates, authors, concepts, methodologies, hypotheses, theories, and philosophies all must be learned and remembered. Doing so efficiently is important to the 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, memory is crucial to daily life.

For this reason, students can potentially perform better in school with 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. Though we place tremendous demands on the memories of students, little scientific information is provided 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 is to provide students with concrete ways of applying memory science to improve their own abilities to learn and remember, a topic that is covered extensively in Chapter 13. Nonetheless, as important as advice is on how to improve memory, the science must come first. Thus, more words in this textbook will be devoted to the science of memory than the wherewithal of improving memory efficiency. But I hope you will be able to improve your own learning by gathering useful strategies from the sections on memory efficiency as well as generating personalized strategies through your own interpretations of theory and data. Indeed, the final chapter is completely devoted to improving memory efficiency. Some readers may want to read the last chapter first.

THE SCIENCE OF MEMORY

We 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, and these are based on evidence, not on the researcher's opinion. In science, a particular theory is useful only if careful and unbiased observations and experimentation support it. For psychological science, data derived from experiments constitute the building blocks of our theories. Our intuitions and guesses about the world have value, but to be science, they must be tested and verified via the scientific method.

Empirical evidence is the product of scientific research. To be empirical evidence, data must be verifiable; that is, another scientist should be able to get the same results by conducting the same or a similar experiment. The data from empirical studies are the building blocks of scientific theory. For example, in earth science, there is overwhelming empirical evidence that, as of 2020, the world's climate is warming. Yes, there are global-warming deniers, but these deniers ignore the overwhelming empirical evidence. As such, those who deny global warming may have faith in their views, but such views do not qualify as science-based views. Note, however, that empirical evidence by itself does not inform us how to act. For example, with respect to global warming, some may advocate changing human industrial activity so as to reduce warming, whereas others may claim that we have to adjust to warming but do not need to eliminate this climate pattern. Both may agree on the basic empirical evidence—that global temperatures are rising—but disagree on what people and governments should do about it.

Empirical evidence: The product of scientific research. To be empirical evidence, data must be verifiable; that is, another scientist must be able to get the same results by conducting the same or a similar experiment.

Similarly, in memory science, empirical evidence is the result of experiments, which can and should be replicable. Therefore, this textbook will devote much space to the methods and results of experiments. Interpretations of what these experiments mean may vary, and you may find different opinions in other textbooks, 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 performance boosters may exist that we do not yet know about, but this textbook will only include empirically tested sources. Empirical data contrast with stories and anecdotes, which may be interesting but do not constitute science. I will try to make scientific principles easier to understand by giving examples and telling a story or two. But although stories may assist good pedagogy, stories and anecdotes do not constitute science. 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 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 to the criminal justice system. Nor can memory researchers "hang around" in places where crimes might occur. This would be dull and tedious work, because except in movies, convenience stores are mostly safe places, and brawls do not break out every night in every bar. Furthermore, witnessing a crime might 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 or a bar brawl and then look at simulated mug shots. This, by and large, simulates the conditions that people might encounter when witnessing a crime 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 generally confirm what has occurred in the lab. Some 135 years of laboratory research have yielded a strong body of knowledge that applies in the real world as well as in 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.

So we will spend most of the book discussing the latest data and most up-to-date theories, but before we do that, 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 showed evidence of introspective behavior at least as long as 40,000 years ago (Bourrillon et al., 2017; Higham et al., 2012). 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 re-enacts memories of great hunting stories. Thus, it is likely that some of these early Stone Age people thought about their own memories.

FIGURE 1.1 ■ Cave painting. It is likely that some prehistoric art re-enacts memories of great hunting stories. When you draw, do you call on events from your memory?

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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. An ancient Egyptian medical manual, known as the Ebers Papyrus, from 1550 BCE (that is, over 3,500 years ago), describes the nature of memory deficits after injury (Khalil & Richa, 2014). Nearly 2,500 years ago, in classical Greece, Plato and Aristotle described theories of memory that sound surprisingly modern. It is likely that many other ancient writings on memory have been lost to history. Certainly, many philosophers and medical professionals have written 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) used two metaphors to account for memory. First, he compared human memory to a wax tablet, a common technology for showing the written word in his day. 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 compared human memory retrieval to a birdcage. 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. Thus, 2,500 years ago, theorists were modeling human memory. More recently, your author compared memory to a teenager's room. It may appear disorganized, but the teenager knows where to find things because of his or her unique organizational schema. 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 135 years ago, when German psychologist Hermann Ebbinghaus (1885/1964) published a volume titled *Memory: A Contribution to Experimental Psychology.* So our history starts with him.

Hermann Ebbinghaus (1850–1909)

Hermann Ebbinghaus was a German psychologist and philosopher who pioneered the scientific study of memory. Until Ebbinghaus published his book (1885/1964), 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 (Nicolas, 2006; Nicolas, Barnes, & Murray, 2015; Otani, Schwartz, & Knoll, 2019). Ebbinghaus is remembered today not only because he was the first memory psychologist but also because he established a number of principles of memory that are still relevant today, in terms of both theory and application. Indeed, a number of his findings are directly applicable to the goals of improving memory efficiency.

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 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 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 (Nicolas, 2006; Otani et al., 2019).

Nonsense syllables: Meaningless syllables that can be given to participants to study that avoid the effect of meaning on memory (e.g., *wob*).

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 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 created and studied more than 2,000 of these trigrams over the course of his experimental study.

Ebbinghaus prepared lists of six to 20 nonsense syllables. He then studied a list until he could free-recall all of the nonsense syllables on the list. Later, he tested himself to see how many syllables 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 easier to master than longer lists. By the end of his study, Ebbinghaus had learned a total of over 84,000 nonsense syllables in over 6,600 lists, during over 800 hours of study (Otani et al., 2019). 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 mastery of a particular list and testing himself again on that list. He found that the longer the retention interval, the more likely he was to forget items from a list. After a retention 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 syllables. This is another truism in memory—the longer the amount of time between learning and remembering, the more will be forgotten.

Retention interval: The amount of time that transpires between the learning of an event or material and when recall for that event or material occurs.

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 Ebbinghaus initially needed 10 repetitions per item to learn a list, he might need only five repetitions per item to relearn the list. Even if Ebbinghaus could no longer remember any items from a previously studied list, he demonstrated savings; it took him less time to relearn the list than to learn the list initially. Although savings diminished with longer retention interval, no matter how long the retention interval was, there was always some evidence of savings. Nearly 100 years later, Bahrick (1984) showed that there are savings in American participants' memory for high school second-language Spanish and French vocabulary 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.

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

Ebbinghaus was keenly interested in measuring forgetting as well as learning. In fact, one of his important contributions was the idea of the **forgetting curve**. He noticed that forgetting happened rapidly at first. In self-tests just a few hours after study, he often found that he had forgotten over 50% of what he had learned. In later tests, though, the rate of forgetting declined. Testing himself a month later for a particular list would still reveal some memory for that list. Like many of his findings, the forgetting curve has been documented repeatedly since Ebbinghaus first studied it (see Schacter, 2001a). Ebbinghaus also found that some variables would affect the forgetting curve, with some making forgetting occur more rapidly, and others, like overlearning, preventing rapid forgetting.

Forgetting curve: A graph that traces the decline of memory performance over time.

MNEMONIC IMPROVEMENT TIP 1.1

Overlearning: If you need to master material, particularly information without intrinsic meaning (e.g., the names of the parts of the brain), continue to study it even after you have mastered it completely. The additional study will ensure that you remember the information for a longer amount of time (the forgetting curve will not be as steep). This may reduce the time you need to restudy information later for a cumulative final exam.

Overlearning: Studying after material has been thoroughly learned.

Ebbinghaus investigated the phenomenon of **overlearning**. Overlearning is 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% on the next day. Thus, studying past the point of mastery led to better long-term retention of that information. This principle has considerable generality and usefulness. If you want to minimize your chance of forgetting something, keep studying it even after you have "gotten it."

MNEMONIC IMPROVEMENT TIP 1.2

Spacing effect: To maximize learning, study the same information at different times. Don't "cram" all at once but space your study over time, both for individual items and for the entire set of material that you need to master. Spacing your study improves your learning efficiency.

Massed practice: When all study occurs in one block of time.

Distributed practice: When study is spread out over time.

Spacing effect: More learning occurs when study trials on the same information are spread out over time than when they occur successively.

Another variable that Ebbinghaus studied 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 list the same amount of time (but on different schedules) through massed practice or distributed practice, he experienced different savings scores for the lists. Even though equal amounts of time went into study, the distributed lists demonstrated higher savings scores than those that were studied all at once. This is now called the **spacing effect**, or the advantage of distributed practice over massed practice (Gerbier, Toppino, & Koenig, 2015; Toppino & Cohen, 2010). 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. After finishing his studies on memory and writing his book on the topic, Ebbinghaus himself moved on to other interests. 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.

Mary Calkins (1863–1930)

Shortly after the publication of Ebbinghaus's book, U.S. psychologist Mary Calkins began her seminal study on the nature of associative learning—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 words, syllables paired with pictures, and words paired with pictures. Calkins then gave the participant the first item from a pair and asked the participant to recall the second item in the association. For example, if the participant had studied a word–word paired associate, such as *rain–cathedral*, Calkins presented the first word in a word–word pair (*rain*), and the participant would have to respond with the target—the second word from the pair (*cathedral*).

Paired-associate learning: Learning the association between two items, such as in language learning (e.g., learning the association *monkey–le singe*).

Shortly after Calkins published her study, the behaviorist tradition would become dominant in U.S. 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, she 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 U.S. students to learn English–French word pairs than 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 discovered the **recency effect**—in immediate recall (when the test occurs right after learning), items that were most recently learned are remembered better than items from the middle of the list.

Recency effect: The observation that memory is usually superior for items at the end of a list; thought to be caused by the maintenance of those items in working memory.

Throughout her career, Calkins campaigned for equality for women, particularly in academia. She became the first woman president of the American Psychological Association and then became president of the American Philosophical Association. Despite that, Harvard University never awarded her the PhD she had earned from its psychology department.

Behaviorism

In the early 20th century, **behaviorism** was the predominant approach in U.S. experimental psychology. Starting with the work of J. B. Watson (1913), behaviorism stipulated

Behaviorism: A school of psychology that focused on the relation of environmental inputs and the observable behavior of organisms, including human beings.

that psychology should focus only on observable, verifiable behavior. Following Watson, behaviorism emphasized the nature of environmental stimuli and their influence on the observable behavior of humans and other animals. Behaviorism took a somewhat paradoxical approach to learning and memory. Learning was a suitable topic of research because it is directly observable—that is, people's behavior changes as a result of experience. However, memory, the stored information in the brain, is not directly observable. Thus, behaviorism focused on learning but deliberately ignored memory. Behaviorists considered not only memory but also thought, concepts of mind, images, and emotions to be inappropriate issues for 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 may get nauseous at the smell of diesel alone, even if there is no dizzying ride in sight. Similarly, an animal may learn that hearing a sound is associated with the release of food from a dispenser. Classical conditioning occurs when the animal moves to the food dispenser when hearing the sound.

Classical conditioning: Learning that a relation exists between a stimulus (e.g., a ringing bell) and an outcome (e.g., getting food); the organism demonstrates a behavior or response (e.g., salivating) that shows that the organism has learned the association between the stimulus and the outcome.

Operant conditioning: Organisms learn to perform responses or behaviors (e.g., pressing a bar) in response to a stimulus to achieve desirable outcomes (e.g., getting food) or avoid undesirable outcomes (e.g., getting an electric shock).

Operant conditioning means that an organism learns to respond in a particular way, because whenever the organism 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 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. Similarly, an animal such as a rat or a monkey will learn to press a lever when that lever causes the release of a desirable food item.

These learning methods appear to be widespread across animals from the simplest to the most complex, including humans. Because of its commonality 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 (Bower, 2000). By the 1960s, the S-R psychologists studying verbal learning started switching to cognitive models of memory. There were simply too many phenomena that classical and operant conditioning did not sufficiently explain and that required thinking about internal memory states to predict.

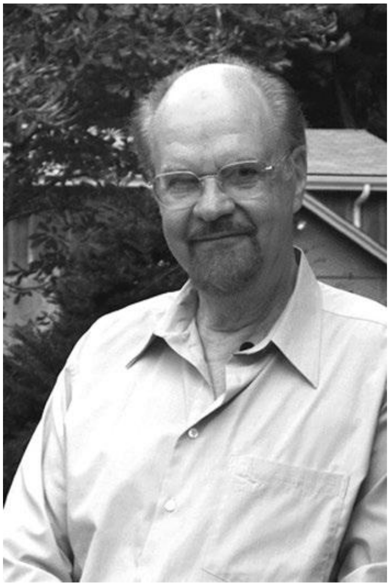
Frederic Bartlett (1886–1969)

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*. 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, such as 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 cultural influences. Inexplicable and magical aspects of the stories tended to be replaced by more rational versions, consistent with the mindset of a Cambridge University student in the 1920s. Bartlett greatly influenced the increasing emphasis on real-world memory and everyday issues in memory research in the 1980s (Cohen, 1996; Wagoner, 2013), and his influence continues today. Bartlett's impact has also been felt in the recent interest in memory accuracy and its opposite, false memory.

Endel Tulving (1927–)

Endel Tulving, a Canadian memory researcher, was originally born in Estonia (see Figure 1.2). Tulving served as a 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. He then went to Harvard University to get his PhD. Eventually, he became a distinguished professor of psychology at the University of Toronto. Perhaps no scientist has made more meaningful and varied contributions to the science of memory than has Dr. Tulving, 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 on which all memory researchers now rely. He developed the encoding specificity principle, the idea that retrieval is better when it occurs in situations that match the conditions under which the memory was encoded.

FIGURE 1.2 ■ Endel Tulving.



Used with permission of Endel Tulving

He was also an early proponent of the idea that long-term memory involves multiple systems. When he introduced the concept of multiple systems, it was roundly criticized; 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 (Storm & Jobe, 2012; Takashima, Bakker, van Hell, Janzen, & McQueen, 2017; 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. Tulving 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 the early 2000s up until his final retirement around 2011, Tulving also became 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.

Cognitive Psychology

Cognitive psychology: An approach to psychology that emphasizes hidden mental processes.

By the 1960s, memory scientists were 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 (Atkinson & Shiffrin, 1968; 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 it 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 to address the issue of representation and study it through careful experimentation.

At the core of theory in early cognitive psychology was the idea of the flow of information (Atkinson & Shiffrin, 1968). 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.

Elizabeth Loftus (1944–)

Elizabeth Loftus is an American psychologist, best known for her pioneering work on eyewitness memory and later for her ongoing work on false memory. Her groundbreaking work on the misinformation effect brought memory science into a number of applied domains, particularly into the courtroom and other legal settings. When she received her PhD from Stanford University in 1970, memory science was just emerging from behaviorist times, and most work was designed to test specific models of how memory worked in general. Loftus modified word-learning paradigms to the study of simulated crimes and accidents and tested to see if the same principles could be found both in the lab and in a more real-world setting. In her early work on the misinformation effect, Loftus showed that subtly introduced misinformation given after an event had been witnessed influenced people's memory of that witnessed event (Loftus, 1974, 1979; Loftus & Palmer, 1974). Loftus has also testified in many trials, claiming that eyewitness memory may be in error, thereby bringing empirical memory science into the legal systems of the United States and many other nations. Later, in the 1990s, Loftus became a leading proponent of the idea that memory is fallible in general, and that normal people have false memories (Loftus, 1992, 2004). This idea greatly impacted some forms of psychotherapy, which were based on the recovery of hidden memories. Loftus's view challenged the assumption of this approach. Loftus continues today to conduct important research on issues of memory and its implication for the legal system. To hear Loftus speak about her work, go to https://www.ted.com/speakers/elizabeth_loftus.

Cognitive Neuroscience

Cognitive neuroscience is the study of the role of the brain in producing cognition. Advances in neuroimaging techniques have led to tremendous gains in our knowledge of the biological processes involved in memory as well as the psychological processes of memory. Neuroimaging allows us to observe the intact living brain as it learns, remembers, communicates, and contemplates. The past 25 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.

Cognitive neuroscience: The study of the role of the brain in producing cognition.

Consider a recent study by Roland Benoit and his colleagues (Benoit, Hulbert, Huddleston, & Anderson, 2015). They were interested in the areas of the brain responsible for suppressing unwanted memories. For example, you may have embarrassed yourself by asking out a person who was not interested in you in return. When you think about this event, you may become embarrassed again, so you try not to think about it. In traumatic memories, one may not want to recall horrible things that happened, so such suppression may be critical to mental health. Benoit wanted to know what was going on in the brain when people are suppressing memories. We often call this examining the neural correlates of memory. We know memory must happen somehow and somewhere in the brain. Thus, looking at the changes in the brain that occur in conjunction with learning and memory may lead to an understanding of the relation between brain and memory.

In this study, Benoit et al. (2015) used a functional magnetic resonance imagery (fMRI), which allows the researchers to look at whether specific areas of the brain are active during particular memory activities—we will review the specifics of fMRI later in the chapter. For here, we only need to know that fMRI can pinpoint specific areas of the brain that are active while someone is engaging in a particular cognitive activity (see Figure 1.3 for what an MRI looks like).

FIGURE 1.3 ■ An MRI of a human brain. The top layer is the cerebral cortex. Also visible is the corpus callosum, which joins the left and right hemisphere.

Thinkstock

Benoit et al. were interested in traumatic memory—that is, memory for unpleasant events that a person may not want to actually recall. Benoit and his colleagues were also interested in why some people can suppress unwanted and unpleasant memories and why people with post-traumatic stress disorder (PTSD) cannot suppress these unwanted memories. Moreover, they were interested in the neural underpinnings of memory suppression. Thus, they asked participants to either recall or suppress the memory of specific faces or specific places while they were being monitored by the fMRI. After each trial, participants reported whether or not they had been successful at suppressing the unwanted memory (or recalling the wanted one). They found a particular area of the brain, the dorsolateral prefrontal cortex, was most active when unwanted memories occurred, even when the person was trying to suppress them. However, greater activity in this area also predicted better control over suppression on future trials. Thus, Benoit et al. concluded that the dorsolateral prefrontal cortex is an important area in the regulation—and suppression—of memory retrieval. Because the dorsolateral prefrontal cortex is also known to be involved in the regulation of many memory processes, Benoit et al. concluded that difficulty in memory suppression is a problem in the process of control over memory rather than with memory retrieval itself, a conclusion they could not have drawn from behavioral data alone. This study illustrates how cognitive neuroscience can tell us more than just information about where things happen in the brain; it can also tell us about how cognitive processes work. This dual nature of cognitive neuroscience makes it important from a psychological perspective as well as from a neurological one.

Cognitive neuroscience research such as this has great promise of answering many questions, both neurological and psychological. Nonetheless, a word of caution is needed here. All psychological scientists agree that the brain is responsible for cognitive processes. Thus, it is not surprising that particular brain processes are correlated with particular aspects of memory. It has to be so. From the point of view of cognitive neuroscience, it is important to know what those brain processes are and exactly how they correlate with memory. However, cognitive psychology endeavors to understand memory at the functional level—that is, how it works in terms of psychological processes. Thus, cognitive psychologists may not always find brain process research relevant to their understanding of the mind. The Benoit study is interesting from a psychological process, because it also implies that suppression is an attentional/control phenomenon rather than an automatic retrieval phenomenon. In this textbook, we take a "memory-science" perspective in which we draw from all psychological sciences that deal with memory. From this perspective, understanding brain processes involved in memory is important.

1. Empirical evidence is
   a. Generally recommended practices in employing recall to improve memory
   b. Any correlational analysis
   c. Data generated from experiments
   d. Dependent measures in psychological experimentation

2. Which of these historical figures is associated with discovering the savings score?
   a. Hermann Ebbinghaus
   b. Elizabeth Loftus
   c. Frederic Bartlett
   d. Mary Calkins

3. Endel Tulving is associated with which of these ideas?
   a. The semantic episodic memory distinction
   b. The study of how memories are experienced by us
   c. The encoding specificity
   d. All of the above
4. An approach to memory that emphasizes hidden mental processes is
   a. Behaviorism
   b. Cognitive psychology
   c. Black box empiricism
   d. Double-blind procedures
5. A scientist who wants to understand the role of the certain areas of the brain in understanding memory would be most influenced by which approach to memory?
   a. Behaviorism
   b. Cognitive neuroscience
   c. Philosophy
   d. None of the above

1. c
2. a
3. d
4. b
5. b

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 members' 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. As memory scientists, however, we cannot simply rely on people's stories and anecdotes. Instead, we conduct experiments that 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 statements or generalizations about how memory works in human beings and get reasonable estimates of 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. *Controlled circumstances* mean that the researcher strives to maintain a situation in which he or she has control over what a participant sees, hears, or can potentially remember. The control allows the researcher to focus on one select issue at a time. Thus, a researcher interested in distributed practice and massed practice will conduct an experiment to determine which condition results in better memory performance. By keeping other conditions constant, the researcher can determine whether distributed practice is truly better than massed practice. In any psychological experiment, the job of establishing controlled circumstances means the careful selection of methods and a

Experiment: Set of observations that occur under controlled circumstances determined by the experimenter.

randomized selection of people to be in the experiment. Because human beings do not all behave alike (unlike, for example, hydrogen atoms), the design of an experiment is an important skill for psychologists.

Independent variables: Independent variables are the factors that the experimenter manipulates across different conditions.

The experimenter controls circumstances by looking at the effects of independent variables on dependent variables. **Independent variables** are the factors that the experimenter manipulates across different conditions. To use a hypothetical example, if an experimenter is interested in whether coffee containing caffeine can improve memory, he or she can manipulate the amount of coffee given to individuals in different groups of participants. In this example, the amount of coffee consumed is the independent variable. Each group receives the same list of words to remember. Thus, one group of people does not get any coffee in advance of studying the list of words; this group is called the control group. A second group gets one cup of coffee before studying the list. And a third group gets four cups of coffee. 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 the experiment has an independent variable (amount of coffee consumed) with three levels (zero cups, one cup, and four cups). Sometime after the participants study the list, we test them to see how many words they can remember. In another experiment, the researchers might be interested in the effects of different kinds of study on test performance. Thus, the researchers could establish an experimental variable with two conditions. In one condition, participants used distributed study, whereas in another condition they used massed study. Given that the total amount of time dedicated to study is kept the same, we can then look at differences in test performance as a function of the kind of study they used. This leads us to the next concept, the dependent variable.

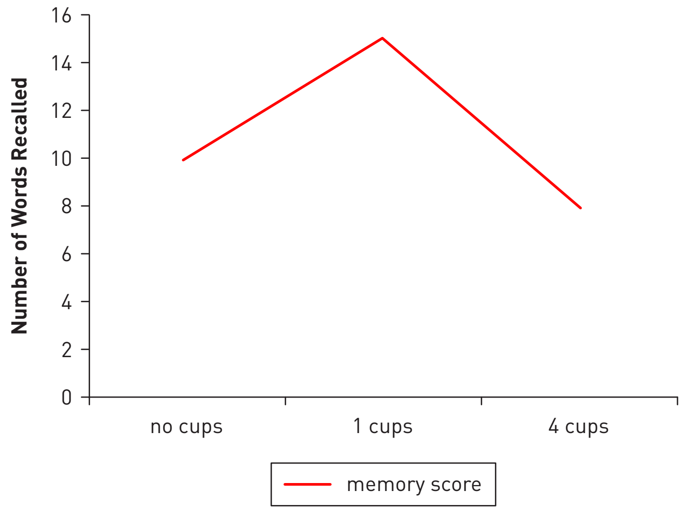
Dependent variables: Dependent variables are the observations that we measure or record in response to the independent variable.

Dependent variables are the observations that we measure or record in response to the independent variable. In the coffee experiment, the dependent variable is the number of words the participants recall from the study list. As memory researchers, we are interested in the effects of the independent variable (amount of coffee consumed) on the dependent variable (number of words remembered). So we measure the number of words remembered for each participant in each condition. We can then statistically compare the outcomes in each condition. This statistical comparison can inform us whether coffee (i.e., one cup) helps us remember words on lists and whether too much coffee (i.e., four cups) makes us too jittery to concentrate on anything (see Figure 1.4). In the study comparing distributed and massed practice, the amount of items recalled would also be the dependent variable. 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, reaction time, and a variety of judgments (to be introduced soon).

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

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 a given 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 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. If enough people are randomly assigned to each condition, the likelihood of individual differences affecting the overall results will be diminished. Second, the participants should not know what you expect to

FIGURE 1.4 ■ Graph of memory as a function of caffeine consumed. This graph shows a potential hypothetical outcome. A small amount of caffeine boosts memory, but a larger amount hurts memory. In fact, research shows that caffeine can hurt memory even at relatively small amounts. *Y*-axis is the number of words recalled.



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. The person administering the memory test to the coffee drinkers should not know if an individual had zero, one, or four cups of coffee, as this knowledge might introduce subtle bias into the experiment. These last two concerns inform what is called a **double-blind procedure**, in which neither the tester nor the participant knows what condition the participant is in.

Double-blind procedure: Experimental structure in which neither the tester nor the participant knows what condition that participant 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 participants to conditions and by keeping both the participants and the experimenters unaware of what condition participants are in. This allows us to be confident that any differences we get between conditions are a function of the independent variable. Then, we can safely draw conclusions about the effects of caffeine on the learning of a list of words.

In memory research, it is crucial to have good dependent measures. 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: A person must generate the target memory based on cues, without seeing or hearing the actual target memory.

Free recall: A person must generate memories with minimal or no cuing of the memories.

Cued recall: A person is given a specific cue and must generate a target memory that corresponds to that cue.

Recall means that a person must generate the target memory. That is, **recall** is the production 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 the items in advance. For example, when someone tells you about their dinner at a restaurant the previous night they are recalling the event. In some cases, a recall test might involve re-enacting 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 Peloponnesian War," and "Describe everything you saw at the scene of the crime," are examples of prompts for free recall. The cue "Tell me about your childhood," provides no information about one's childhood. Thus, all the information recalled is freely selected by the rememberer. In memory experiments, free recall is more likely to be "Write down all the words from the study list."

A second variant of recall is often used in memory experiments. **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 *walnut–le noyer*. In a cued-recall test, you might receive the English word (*walnut*) and be asked to recall the French word.

Recognition

Recognition: Person must identify the target memory from among a set of presented item(s).

Old/new recognition: Person must decide whether an item was on the study list.

Forced-choice recognition: Person must identify the answer from among a series of possible answers.

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 memory with what he or she sees on a list. Recognition can be **old/new recognition**, in which the person has to decide whether 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. To summarize, 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 of them.

Implicit Memory Tests

Implicit memory tests draw on the nonconscious aspects of memory. 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.

Implicit memory tests: Tests that draw on the nonconscious aspects of memory.

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. However, in Eich's study, the focus was on implicit memory, not attention. Eich showed that in a test of free recall, the participants remembered very little to nothing at all of the unattended stimuli. In contrast, Eich found that, even though participants could not consciously recall the items presented to the unattended ear, there must have been some nonconscious processing of those items, because the processing 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 such as, "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 which of two spellings they should choose. Participants who had heard these words in the unattended ear were more likely to spell them according to the context in which they had heard them, even though they could not consciously remember having heard the words. 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.* Thus, even though the participants could not consciously recall what the words were, exposure to the words affected their performance in an implicit memory test. This increase (or decrease) in performance based on some prior processing is known as *priming* (Jacoby, 1991). Such priming of implicit memory is often important in helping patients with impaired memory (Redondo, Beltrán-Brotóns, Reales, & Ballesteros, 2015).

Reaction Time

Reaction time is the measured amount of time required to perform a particular task. Different tasks will require different amounts of time to perform, revealing the time course of the underlying processes. Reaction time varies as a function of the number or difficulty of the underlying memory processes (Sternberg, 1969). Sprinters reacting to a starter's pistol initiate their sprint in less than 200 milliseconds. Hitting a button as fast as possible if it is red may take about 200 to 400 milliseconds, but hitting a button if it is the same color as what you just saw may take a bit longer. The reaction time to determining whether a series of letters, such as potchbork, is a word or not may take nearly one second (Popov & Hristova, 2015). Thus, longer reaction times usually reflect more internal cognitive processing. With respect to retrieval from memory, Dewhurst and Conway (1994) looked at reaction times of old/new recognition judgments. They measured how

Reaction time: The measured amount of time required to perform a particular task.

long it took to decide whether or not a word had appeared in the experiment earlier. They found that if people felt as though they "remembered" the items from the earlier list, they had faster reaction times than if they felt as though they "knew" the items were from the earlier list. We will discuss the remember/know distinction later in Chapter 4.

Source Judgments

Source judgments: Our attributions of where or from whom we learned something.

Source judgments are our attributions of where or from whom we learned something rather than the memory content itself. For example, a student may recall that it was the teaching assistant and not the professor who told her that a particular chapter would be on the exam. Or a person may recall that she imagined winning the U.S. Open Tennis tournament rather than recalling actually having done so in real life. With source judgments, the task is to identify who told you the fact, not necessarily to remember the event or fact itself. In some cases, we may remember an event or fact but not remember the source. 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 television nature show. However, in many cases, remembering the source is vital to your appraisal of the memory. Consider a situation in which, while gossiping with a friend, you mention that the actress Jennifer Lawrence 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.

Researchers test source judgments by asking people from whom they heard information (Foley & Foley, 2007). In some experiments, for example, two individuals, one male and one female, read a list of words. The two readers alternate, with one reading one word and the other reading the next 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 (dating a movie star or being elected president, for example), but it is important to recognize these memories as being internally generated rather than based on real events. Recently, there has been work on whether we can identify whether other people's memories are real or imagined (Clark-Foos, Brewer, & Marsh, 2015; Nahari, 2018).

Reality monitoring: Our ability to distinguish whether our memory is of a real or an imagined event.

Metamemory Judgments

Metamemory: Our knowledge and awareness of our own memory processes.

Judgments of learning: Predictions we make as we study items of the likelihood that we will remember them later.

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. For example, when you say, "I am good at remembering faces," you 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 (Cleary & Claxton, 2015). 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 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 as noted, tip-of-the-tongue states. Metamemory will be covered extensively in Chapter 9.

Summary of Memory Measures

These six categories (recall, recognition, implicit memory tests, reaction times, source judgments, metamemory judgments) make up the vast majority of measures that memory scientists use to study human memory. Nearly every behavioral experiment that we will cover in this book makes use of one of these six 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

Neuropsychology is the study of patients with brain damage. The study of patients with brain damage has a long and distinguished history (Feinberg & Farah, 2000). As mentioned earlier, ancient Egyptian doctors noted that blows to specific areas of the head resulted in characteristic behavioral change. 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. For example, damage to an area of the brain called the hippocampus can cause amnesia. Damage to an area of the brain called Broca's area causes deficits in the ability to produce speech. You can see the change in language behaviors based on damage to Broca's area.

Neuropsychology: The study of patients with brain damage.

For many patients, the damage is too wide, too diffuse, or too minor to be of interest to research 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, those patients with 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. Other patients might have damage restricted to areas of the right frontal lobe, which will result in difficulties in remembering the source of information. We will discuss several famous neuropsychological patients in Chapter 2. By probing the nature of brain damage, we can develop a model of the relation between a particular brain region and memory function.

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 experiments, 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 so that researchers can determine what kinds of stimuli elicit responses in a given 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: Refers to a set of techniques that allows researchers to make detailed maps of the human brain and assign functions to particular regions in the brain.

Neuroimaging techniques are advanced technologies that allow researchers to visually examine intact human brains as well as injured brains. This area has seen marked growth in recent years; it will be briefly introduced here but covered in much greater depth in Chapter 2. Neuroimaging techniques allow scientists to correlate cognition and behavior with function in normal, active brains. In fact, neuroimaging techniques allow us to trace the flow of information in the brain as individual people think. As of yet, researchers cannot tell what a person is thinking, but when a person reports what he or she is thinking, reliable correlations seem to exist between that person's reports and particular parts of the brain as well as the connections between them. 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 and how they unfold over time. To determine where in the brain a particular process is occurring, scientists can use neuroimaging to develop detailed spatial maps of the brain showing which areas are active during which cognitive task. To determine the flow of activity in the brain over time, scientists can use neuroimaging to take pictures of the brain in quick succession to determine the time course of processes. Examining the relation between brain processes and memory processes has led to a greater understanding of both how the brain works and the cognitive underpinnings of memory.

The field of neuroimaging is rapidly evolving, but five of the major techniques are reviewed here. It is important to note, however, that PET technology is rapidly being replaced by the better (and safer) MRI technologies. We will explore these techniques in greater depth in Chapter 2, but introducing them here will help you, via distributed learning (discussed earlier in this chapter in the section on Ebbinghaus), to understand them when you encounter them again later.

EEG (electroencephalography): Using electrodes to measure the electrical output of the brain by recording electric current at the scalp.

1. **EEG (electroencephalography)**. In EEG, often as many as 128 electrodes are placed on various places on the scalp. Each electrode can then pick up an electrical signal from the brain's total electrical output. Because areas of the brain that are active will generate more electric output than those that are not active, we can see where things are happening in the brain by comparing these outputs. The electrodes pick up a continuous electric signal, so measurements can be made very quickly, 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. In many memory science applications, EEGs are recorded repeatedly in response to specific stimuli. These recordings are then averaged to create an event-related potential (ERP). Many cognitive tasks produce ERP-identifiable patterns that mark a particular cognitive task.

MEG (magnetoencephalography): Using a magnetic sensor to detect the small magnetic fields produced by electrical activity in the brain.

2. **MEG (magnetoencephalography)**. A magnetic sensor detects the small magnetic fields that are produced by the electrical activity in the brain. In this way, MEG is similar to EEG in that it can detect rapid changes in the brain, although its

temporal resolution is less than that of EEG. However, because the magnetic fields are less distorted by other parts of the body (e.g., bone), MEG can produce better spatial maps of the brain than can EEG, though not as good as fMRI. MEG is useful today because it represents a compromise between good spatial resolution and good temporal resolution.

3. **PET (positron emission tomography)**. PET is rapidly being replaced by fMRI and is included here mainly for historical purposes. In PET, a small amount of radioactive tracer is injected into a person's bloodstream. The tracer travels to all areas of the body, including the brain. Areas of the brain that are active require more blood than areas that are resting. This is a 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 radioactive emissions and determines where they are 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.

PET (positron emission tomography): Radioactive chemicals are placed in the blood, allowing scientists to obtain a three-dimensional image of the intact brain.

4. MRI and **fMRI** (magnetic resonance imagery and **functional magnetic resonance imagery**). In these techniques, people are put in large magnetic fields that align the molecules in the brain (see Figure 1.3). Then, as blood flows into areas of the brain, the molecules' organization is disrupted. A specialized camera detects this disruption. The fMRI technique traces oxygen molecules in the blood, measuring which areas of the brain are more active during any particular cognitive task. Because fMRI can take a picture every 50 milliseconds, the researcher can determine both where in the brain a particular memory function is taking place and how it changes over time (Yoo et al., 2018). Thus, fMRI has an advantage over EEG, MEG, and PET, although it is still slower than EEG and MEG. It is safer than PET because no radioactivity is involved. In fact, research suggests there are no health risks associated with having an MRI. Its only current drawbacks are its expense and that you cannot place an electronic device, such as a computer, into the magnetic field without destroying the electronic device. This requires scientists to obtain data from participants using a variety of mirrors and levers.

fMRI (functional magnetic resonance imagery): Magnetic fields create a three-dimensional image that can capture both the structure and function of the brain.

5. **TMS (transcranial magnetic stimulation)**. There are a number of technologies that we are grouping under the general label of TMS. All of these techniques stimulate the brain by electric current. In TMS, a magnetic field generator, often called a coil, is placed on the head of a willing participant. The coil induces electric currents in the region of the brain beneath the coil. TMS has a number of clinical applications, which we will discuss in the next chapter (Hickin, Mehta, & Dipper, 2015). For research, researchers can apply TMS to various parts of the head and observe the behavioral changes in the participant. These changes are relatively mild and short-lived but allow researchers to experimentally examine brain region and function. In most cases, once the current is removed, the changes in cognition disappear, and there do not appear to be any long-term negative effects of TMS. For example, Pergolizzi and Chua (2015)

TMS (transcranial magnetic stimulation): Using a magnetic coil to electrically stimulate particular areas of the brain. This stimulation causes cognitive changes in the participant.

used direct current TMS to stimulate the parietal lobes of their participants. While under stimulation, the participants were more likely to falsely recognize words as being seen previously, which were related in meaning to words seen earlier but had not been seen earlier themselves. That is, participants were more likely to say that the word *lawyer* was on the list when they had seen the word *attorney* when they were getting TMS stimulation than when not. One of the important advantages that TMS technology has over other technologies is that the researcher has experimental control over where the TMS is applied. Thus, changes that result in a person's cognition are caused by the TMS. In fMRI, we can only correlate changes in cognition with changes in brain state. For a video clip of TMS, go to https://www.youtube.com/watch?v=xLiHRG9l9W4.

Throughout the book, we will be discussing research generated from each of these 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 for 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.

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1. In a memory experiment, the researcher varies the amount of study time given to participants and measures how much they remember as a function of study time. Amount of study time is the ________, and how much they remember is the __________.
   a. Experiment; recognition quotient
   b. Independent variable; dependent variable
   c. Reaction time; source judgment
   d. Random assignment; experimental control

2. In an experiment, a participant is asked to determine on which of two projectors they saw a particular video. This task must map onto
   a. Recall
   b. Neuropsychology
   c. Source monitoring
   d. Implicit memory testing

3. A researcher induces a mild electric current into the frontal lobe of the brain of a participant in order to determine if source monitoring is affected. This technique is called
   a. Transmagnetic cranial stimulation
   b. Functional magnetic resonance imagery
   c. Positron emission tomography
   d. Neuropsychological testing

4. A person must decide if a word, such as *pasture*, was seen on an earlier list of words. This method is called
   a. Free recall
   b. Old/new recognition
   c. The tip-of-the-tongue phenomenon
   d. Reality monitoring

5. Judgments of learning are
   a. A neuroimaging technique that allows one to measure the brain directly
   b. A measure of free recall
   c. Predictions we make as we study items about future remembering
   d. Our ability to distinguish whether our memory is of a real or imagined event

1. b
2. c
3. a
4. b
5. c

CULTURE AND MEMORY

The role of culture in human memory has a long history but until recently has been an understudied topic. Bartlett's (1932) seminal study on the learning and remembering of stories emphasized how different cultural contexts played into our memory for narrative. However, the Ebbinghaus tradition in memory research assumes that all people have fundamental characteristics in common—perhaps based on common brain organization.

Q. Wang (2018) has documented important differences in the emphasis on different memory systems and strategies across cultures. In particular, her work has focused on how Western families focus on shared autobiographical knowledge, whereas Chinese families focus on semantic knowledge. Moreover, as will become apparent as one reads the many experiments described in this book, much of cognitive psychology is based upon the learning and remembering of Introductory Psychology students. Whereas it is not unreasonable to think that such people represent a diverse and representative sampling of human beings in general, it is also important to examine how specific patterns of findings change across culture. For example, recent research shows how important the relation between working memory (to be discussed in Chapter 3) and literacy is (Guida et al., 2018). Cross-cultural data on memory will be presented in this book when they are available.

IMPROVING MEMORY EFFICIENCY

One of the themes of this book is that you can use the principles advanced here to improve the efficiency of your own learning and remembering. 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 write 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: Improving memory efficiency is hard work! Yet the hard work can be directed in thoughtful and informed ways to be more efficient. Memory science knows much 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 with a discussion of types of memory. Chapter 3 will outline the current theories concerning how many different memory systems human beings 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; Sun, 2012). For example, the learning and remembering required to play the violin are 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 in school. Thus, the principles that govern memory improvement are going to differ between one domain and another. Visual imagery mnemonics, for example, are useful for mastering new-language vocabulary (Thomas & Wang, 1996) but of little use in learning to play a new musical instrument. Similarly, linkword mnemonics are useful in learning name–face associations, but they will not help you remember the name of your kindergarten teacher when somebody asks you many years later. Having said that, a number of principles do apply across a wide domain of memory systems. The spacing effect, described in the section in this chapter 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.

Although students are usually concerned about ways in which they can improve their ability to remember school-based 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 someone better remember to take out the garbage. 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; Oates, Peynircioğlu, & Bates, 2015). For example, 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. If you need to remember to pick up your kids at school (perhaps normally your spouse's task), you can carry around a photograph of them, perhaps by placing 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 will see it and won't drive to school or work without stopping at the library.

Prospective memory: Memory for the things we need to do in the future.

We can improve the efficiency of our learning and remembering. In this book, I hope to offer a number of ways in which memory science has shown that memory can be made more efficient. 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. 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.

In the last section of 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.

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 white-water rapids that would drown the untrained person. Some human beings memorize the Bible or the Koran, whereas others can tell you the complex ingredients of 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 it 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 the learner who does not.

2. **Learning and remembering have a biological/neurological basis.** Our brains are our biological organ of learning and remembering. The past two decades, with the advent of neuroimaging, have seen 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; other memories, such as of a friend's wedding ceremony or the time you hit a home run in Little League, may last a lifetime. We have different neurocognitive systems to handle these different kinds of memory. Chapters 3 and 4 will explore the nature of these memory systems.

4. **The efficiency of 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 techniques involve managing our existing resources and efficiently using our time. We can apply a number of principles consciously to our efforts both to learn information and to remember it. Each chapter will offer memory hints, based on the research discussed, as to how you can improve some aspect of learning and remembering. And then, in Chapter 13, an entire chapter will be spent on this 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 cognitive psychology and 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 some that benefit memory performance. Following Ebbinghaus, other scientists such as Mary Calkins, Frederic Bartlett, Endel Tulving, and Elizabeth Loftus 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, EEG, and TMS. Also introduced is the idea that culture interacts with memory. Four overarching themes were introduced, focusing on the active nature of learning and remembering, its status as a biological process, the multiple systems that comprise it, and the principles of learning and remembering we can use 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

Review Questions

Who was Hermann Ebbinghaus, and what were his important contributions to memory science?

How can the spacing effect be used to improve memory?

How did the contributions of the science of behaviorism and cognitive psychology to modern understanding of memory differ?

What are the key components of a memory experiment?

What is the difference between recall and recognition?

What are source judgments? What are metamemory judgments?

How does studying neuropsychological patients aid in understanding the nature of memory and the brain?

Describe three techniques of neuroimaging. What are the advantages and disadvantages of each?

Why is understanding culture important to understanding memory? How might memory differ across culture?

What are the four themes of the book? Why are they important?

Online Resources

For a good website on the general philosophy of science, go to http://teacher.pas.rochester.edu/phy_labs/appendixe/appendixe.html.

For Hermann Ebbinghaus's book, see http://psychclassics.yorku.ca/Ebbinghaus/.

For more on Mary Calkins, go to https://www.apa.org/about/governance/president/bio-mary-whiton-calkins.

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

For more on Endel Tulving, go to http://www.science.ca/scientists/scientistprofile.php?pID=20.

To hear Loftus speak about her work, go to https://www.ted.com/speakers/elizabeth_loftus.

See a patient with Broca's aphasia at http://www.youtube.com/watch?v=f2IiMEbMnPM.

For an in-depth discussion of fMRI, go to http://science.howstuffworks.com/fmri.htm.

For a glimpse of TMS, see https://www.youtube.com/watch?v=xLiHRG9l9W4.

For the latest on memory research, go to http://www.human-memory.net.

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