

Human Memory

Gabriel A. Radvansky

3
EDITION

Human Memory

This book provides a complete survey of research and theory on human memory in three major sections. A background section covers issues of the history of memory, and basic neuroscience and methodology. A core topics section discusses sensory registers, mechanisms of forgetting, and short-term/working, nondeclarative, episodic, and semantic memory. Finally, a special topics section includes formal models of memory, memory for space and time, autobiographical memory, memory and reality, and more. Throughout, the author weaves applications from psychology, medicine, law, and education to show the usefulness of the concepts in everyday life and multiple career paths. Opportunities for students to explore the assessment of memory in laboratory-based settings are also provided. Chapters can be covered in any order, providing instructors with the utmost flexibility in course assignments, and each one includes an overview, key terms, *Stop and Review* synopses, *Try It Out* exercises, *Improving Your Memory and Study in Depth* boxes, study questions, and *Putting It All Together* and *Explore More* sections.

This text is intended for undergraduate or graduate courses in human memory, human learning and memory, neuropsychology of memory, and seminars on topics in human memory. It can also be used for more general cognitive psychology and cognitive science courses.

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For Amy

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PREFACE

This book is a student's guide to human memory, the properties of memory, theories about how memory works, and how an understanding of memory can give us a better idea of who we are and why we do what we do. Although I have tried to provide a reasonably comprehensive survey of many issues of the modern study of human memory, my main concern is the audience. Most college classes on human memory consist largely of psychology majors who are planning to go on to some field of psychology other than memory research, such as clinical or social psychology. Many others plan to go on to nonpsychology fields, such as medical or law school. Other students are not psychology majors but are taking the class because they think human memory would be something interesting to learn about (and they are right). Only a small minority of students will plan to do research on memory. As such, I have tried to write this book with the goals, interests, and backgrounds of the majority of the students in mind, while still providing enough information and detail to satisfy the "memory" student. I have taken a number of steps along these lines.

First, in addition to foundational topics that are necessary for a basic understanding of how memory works, I have tried to focus on topics that will be helpful and useful whatever the student's ultimate goal. I have tried to avoid going into detail about the minutiae of various topics and have instead focused on the big picture. However, there may be cases where I do present a number of different experimental outcomes or theoretical positions. I have done this to provide the student with a sense of the difficulty and complexity of studying human memory, and the degree of careful and rigorous thinking and action that are needed to get at the truth of the human condition.

I mention several times that a particular study was conducted using students from this college or that university so that readers can associate with the information presented in this book. The participants in these studies are the same sort of people sitting in your classroom. I have tried to avoid language that would alienate a student, which can put up a barrier between the student and the material.

I have also tried to present the materials about memory from a number of

different perspectives. Some of these come from experimental research on memory itself, such as perspectives from behavioral data, neurological data, and computational modeling. In addition, I present details about how various topics relate to work outside the realm of memory research, such as work in social, clinical, or developmental psychology, or even fields as far-flung as law enforcement.

A quick survey of this book will reveal that it has a lot of chapters. Perhaps too many for a single class term. That's O.K. That was the intention. The field of memory is broad, and different classes place different emphases on different topics. I would expect that most classes would be assigned and use [Chapters 1–9](#) of this book. This is the background and core knowledge that one needs to understand human memory. Then, I would expect that the instructor would select those choices from [Chapters 10–18](#) that best suit their class and its goals. Of course, if you want to assign all 18 chapters, go for it!

I have also sprinkled throughout the book a number of boxes to highlight different things. These boxes serve to accomplish three goals. First, some of these are Try It Out boxes, which provide descriptions of how to do studies that can illustrate salient findings in memory research. These are helpful for any students who might have a lab section associated with their course. Even if not, they give the student a better idea of how to set up and test memory, and the scientific enterprise more generally. Second, some of these are Study in Depth boxes, which show detailed accounts of actual studies in memory research, how they were set up, who was involved, the methods that were used, and the results that were found. These provide an opportunity for students to better grasp the scientific method as it is applied to the study of memory. This includes the identification of a problem, the derivation of the materials and the experimental design, the manipulation of various independent variables, the use of an appropriate dependent variable, the data collected, and how it was interpreted. Finally, some of these are Improving Your Memory boxes, which illustrate, in a more direct way, how the basic findings and principles of research psychology can be extended to real life. Research studies in human memory can often seem artificial and so strongly laboratory-bound that it is hard for people who are not experts in the area to see what the value of this work may be to the bigger picture and their own lives. I hope that these boxes go some way to achieving this aim.

Finally, I would like to thank the various people who have helped me along with the development of this book. These include Amy Radvansky for reading through every single chapter to make sure that what I wrote actually makes sense, Kyle Pettijohn for his work on the effective presentation of this material,

Jerry Fisher for spotting more typos than I would care to admit, all of my graduate students over the years, all of my students in my learning and memory classes at Our Lady's university, and, finally, all of the assistance from people at Taylor and Francis, including my editor, Paul Dukes, as well as Rachel Severinovsky, Debra Riegert, Jan Baiton, Tamsyn Hopkins, Hugh Jackson, Susan Leaper, Richard Sanders and Abigail Stanley who worked so hard to make this book a reality. So, thanks!

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PART 1

Background

CHAPTER 1

Overview and History of Memory Research

Memory is perhaps the most central aspect of human thought. Any question about human nature requires an understanding of memory. Memory makes us who we are, and it is one of the most intimate parts of ourselves. This may be why when we get close to someone there is a sharing of memories. Some people feel that the study of human memory is the closest one can get to a systematic study of the human soul. The aim of this book is to provide you with a survey and guide to what is known about human memory. As with most courses, there are a number of facts and ideas to learn. However, as any good instructor will tell you, the slow accumulation of facts is not the main point of course work. The primary aim is to provide you with a deeper understanding and appreciation of some aspect of the world—and, hopefully, yourself.

A SMATTERING OF DEFINITIONS

Before diving into the subject matter, we need to define how the terms *memory* and *learning* are used. Although it would seem to be a straightforward task, precise, satisfactory definitions can be somewhat elusive. The primary subject of this book is, of course, memory. So what is memory? Well, the problem, and the beauty, of this term is that it has many meanings.

Memory

The word **memory** has three primary definitions (Spear & Riccio, 1994). First, memory is the location where information is kept, as in a storehouse or memory store. Second, memory can refer to the thing that holds the contents of experience, as in a memory trace or **engram**. In this sense, each memory is a different mental representation. Finally, memory is the mental processes used to acquire (learn), store, or retrieve (remember) information. Memory processes are

acts of using information in specific ways to make the information available later or to bring that information back into the current stream of processing, the flow of one's thoughts.

Learning

The term **learning** refers to any change in the potential of people to alter their behavior as a consequence of the experience of regularities in the environment. Obviously, learning and memory are closely related. For something to be remembered, it must first be learned. Because of historical circumstances, these terms have become somewhat disconnected in the language of psychology. "Learning" has come to refer more to the acquisition of associations in the context of studies of conditioning often done using animals, such as a rat learning a maze. In this book I use learning in the way it is conventionally used by people in the world, although I may occasionally use it in the more restricted sense.

METAPHORS FOR MEMORY

The human mind is the part of ourselves of which we have the most intimate awareness. Our experiences are our thoughts. That said, most of its workings are not open to direct inspection. You can't see "thinking." Moreover, every experience that the mind has changes it in some way. By reading this sentence, you are changed. These issues lead to a number of problems in trying to understand memory. One has to be clever and develop ways to study memory (see [Chapter 3](#)). More relevant here is that there is no simple and direct way to talk about memory. Because of this, people often talk about it in indirect ways, using **metaphors**.

Roediger (1980) has compiled a list of metaphors of memory that have been used over the centuries (see [Table 1.1](#)). Some of these metaphors express the idea that memory is a recorder of experience, such as a wax tablet, a record player, a writing pad, a tape recorder, or a video camera. Others imply that different types of memories, knowledge, and times in our lives are stored in different places. These include such metaphors as memory being like a house, a library, or a dictionary. In contrast, another concept is that memories can also be intertwined and interconnected, like a switchboard or network.

TABLE 1.1 *Various Metaphors for Memory*

Metaphor	Examples
Recorder of experience	Wax tablet, record player, writing pad, tape recorder, video camera
Storage locations	House, library, dictionary
Interconnections	Switchboard, network
Jumbled storage	Bird in an aviary, pocketbook, junk drawer, garbage can
Temporal availability	Conveyor belt
Content addressability	Lock and key, tuning fork
Forgetting of details	Leaky bucket, cow's stomach, acid bath
Reconstruction	Building an entire dinosaur skeleton from fossils
Active processing	Workbench, computer program

Source: adapted from Roediger (1980)

Memory is not passive. Some metaphors capture its dynamic characteristics. For example, the process of retrieving one from the chaotic jumble we have accumulated has led to the idea that searching for memories is like trying to catch birds in an aviary or looking for something in a junk drawer, or even a garbage can. This also goes along with the idea that memories are harder to get at over time, as if they were being led away on a conveyor belt. Often a search is required to find memories that meet a current need, like a lock and key, or a tuning fork resonating with a note. Memory retrieval is further complicated by the fact that much of what is stored is forgotten, leaving only a portion of the original, like water in a leaky bucket, or the degrading effects of a cow's stomach or an acid bath. This loss of knowledge requires people to re-create the missing pieces of a memory, using a constructive process, perhaps like reconstructing a dinosaur from the fragments of bones left behind. Finally, there is the active manipulation of information, as if memory were a workbench or a computer program.

The large number of metaphors should give you the idea that memory is a complex thing. Because of its ephemeral nature, we use our knowledge of more concrete and better understood concepts to help us make sense of it. The most dominant metaphor for memory is the literacy metaphor (Danziger, 2008). The advent of written language led people to view memories as things that are written down and put somewhere. This leads to the near universal conception of memory involving encoding, storage, and retrieval, much like writing books and

storing them on a shelf. This metaphor treats memories as discrete units, like books or pages, which may or may not correspond to how the brain parses our experiences. The dominant modern version of this is the computer metaphor, which drove the cognitive revolution of the mid-twentieth century.



PHOTO 1.1 According to one metaphor, memory is like a leaky bucket, being able to hold things for a period of time but constantly losing information

Source: ConstantinosZ/iStock/Thinkstock

Before moving on, let's look at one more metaphor that is very inaccurate: the idea that memory is a muscle. That is, the more you use your memory, the better it will be. In other words, simply memorizing things will make memory better. There is no evidence to support this. Instead, it is not how much you use your memory but how much information you have in it that is important. Memory is not like a muscle, but more like a key collection. The more keys you have, the more locks you can open.

Stop and Review

The terms *memory* and *learning* are used in specific ways in psychology. In general, *memory* refers to the storage and retrieval of information, and research is more likely to involve humans. *Learning* has a greater association with studies of conditioning that are more likely to involve animals. Memory is not open to direct inspection, so we need metaphors to try to apprehend it. Each metaphor carries a degree of imprecision, but also captures some important characteristic. Various metaphors capture the idea that memory is a recorder of experience, is organized and interconnected, is jumbled and requires a search (better if you have the appropriate keys to unlock them), and actively operates on information. The most dominant metaphors are the computer and literacy metaphors, which treat memories like files on a computer or as if they were stored on shelves, like books in a library.

HISTORY OF MEMORY RESEARCH

Questions about the nature of memory extend back millennia. However, a true systematic, quantified, and rigorous assessment of the nature and limits of human memory did not begin until the end of the nineteenth century. In this section, we review some of the major players in the history of memory research, starting from the ancients.

Ancient and Pre-Modern Thinkers

Our understanding of memory has developed over time and has been influenced by people ranging from the great philosophers of ancient Greece to those from modern times. One of the first philosophers to record his thoughts on memory

was Plato (ca. 428–347 B.C.). Plato was the seminal rationalist philosopher who emphasized thought as a means of understanding the world, and he de-emphasized empirical observation because it could be distorted by perception. He was a dualist who believed that the mind was a different and separate entity from the body. Understanding of how the mind and memory worked depended on understanding that the nature of innate, inborn knowledge was the foundation of human thought. Memory was the bridge between the perceptual world and the rational world of idealized abstractions (Viney & King, 1998).

Plato also provided the metaphor of memory as a wax tablet, holding the impressions of experience. This metaphor also conveys the idea that memory quality varies depending on the quality of the wax (the state of the person) and the pattern that is impressed (how well the information is encoded). The better the impression, the easier it is to retrieve it later or to compare it with other impressions. Furthermore, the wax can be altered or erased so that an impression is lost, thus conveying the concept of forgetting.

Plato's most prominent pupil was Aristotle (384–322 B.C.). Like any good student, Aristotle's ideas were at odds with his mentor. Specifically, whereas Plato was a rationalist, Aristotle was an empiricist who believed that reality itself, not an abstract, perfect realm, was the basis of inquiry. One of Aristotle's contributions is the idea that memories are composed of associations among various stimuli or experiences. As you will see, there are many theories of memory that are associationistic, such as accounts of priming, interference, or even the creation of false memories. There is a pervasive idea that understanding how various elements are mentally linked to one another can capture the structure and processes of memory.

These linking relationships often follow Aristotle's three laws of association: similarity, contrast, and contiguity. That is, memory associations provide links to ideas that are similar in nature, are the opposite on some critical dimension, or occurred near one another in time.

The desire to understand memory did not stop with these philosophers. This inquiry has been continuously pursued. For example, St. Augustine (354–430) spends a great deal of time in Book X of his *Confessions* on the topic of memory, covering the subject in a way that is familiar today. Some thinkers developed conceptions of memory that were often not pursued. For example, Robert Hooke (1635–1703) developed a surprisingly insightful theory of memory. However, his work was generally overshadowed by Sir Isaac Newton (1643–1727), whose work further hurried Hooke's ideas into obscurity (Hintzman, 2003).

Darwin and Evolution

One person who had a great impact on scientific thinking in general, including human memory, was **Charles Darwin** (1809–1882). Darwin, of course, is best known for his theory of natural selection, but his ideas influenced psychology as well (see the entire February–March 2009 issue of *American Psychologist*). The central idea is that, within a species, changes occur as a result of variation that can either be passed down to or removed from subsequent generations through the process of *natural selection*. Through this process, species develop features or abilities that allow them to become better adapted to their environments. The same could be said of memory. Many theorists are either implicitly or explicitly guided by the idea that memory has evolved to capture many major characteristics of the environment and to perform specific tasks (Glenberg, 1997; Klein, Cosmides, Tooby, & Chance, 2002; Shepard, 1984). Different types of memories capture meaningfully different types of information. Also, because many species are evolving along similar trajectories, nonhuman animals can sometimes be used to study issues of memory that require more control than is either practically or ethically possible with humans.

This evolutionary aspect of memory has an influence on how people think about the mind, behavior, and genetic influences. In some sense all human behavior has a genetic component (Turkheimer, 1998). The very existence of our brains in the interiors of our skulls requires that we have brain-building DNA, and all of our thoughts and memories depend on our biologically constructed brain. Any psychological state corresponds to a neural state. Thus, our thoughts and memories have an important genetic component. However, our DNA does not cause our brains to have the *exact* configuration that we have at the moment. This is due to our long history of experiences. Similarly, although our thoughts depend on neural hardware and processes, it does not mean that the most direct way to understand memory is by a detailed understanding of the underlying neuro physiology. That said, the more you understand the underlying neurological components and processes, the better you will understand the higher-order operations. For this reason, I include several descriptions of this influence to broaden your understanding.

Philosophy of Mind

Another important group of thinkers that has influenced ideas about memory are the British empiricists, including George Berkeley (1685–1753), John Locke

(1632–1704), John Stuart Mill (1806–1873), and David Hume (1711–1776). Perhaps the most significant of their ideas involve association, a concept originally conceived by Aristotle but worked up into grand form by the empiricists. Associationism maintains that memories are largely composed of interconnections among various simple concepts or ideas. The influence of this view is seen clearly in [Chapter 10](#) when we discuss formal models of memory. This role of associations in memory can be easily illustrated. Things in the world are rarely treated by people as isolated entities or properties. Instead, we are often reminded of other, related experiences that included them. For example, when I eat a certain brand of cookies, I am reminded of my childhood because those were the kind of cookies my mother bought.

The empiricists' idea that memory is composed of associations has had a major influence on theories of human memory. However, the philosophical antagonists of the empiricists, the rationalists, including René Descartes (1596–1650) and Immanuel Kant (1724–1804), have also had an influence. While the empiricists characterized memory as a passive collection of associations built up from the environment, the rationalists took the view that the mind is actively involved in the building of ideas. This can be seen in various theories of memory that involve the active construction and reconstruction of memories, such as those found in schema theories (see [Chapter 9](#)).

Early Memory Researchers in Psychology

Psychology as an independent discipline arose in the second half of the nineteenth century. Since then many people have influenced memory research. While a few influential contributors are covered here, it should be kept in mind that the study of memory did not always move at a steady pace. Sometimes people develop ideas that have the potential to move the field forward but, for whatever reason, are not noticed at the time. These theories fall by the wayside, never to be heard from again. However, a few may capture the attention of future generations, who discover the earlier, neglected work. For example, in memory research, Richard Semon (1859–1918) had a theory of memory in the first decade of the twentieth century that incorporated many ideas about the process of retrieval. However, his contemporaries largely ignored these ideas and his insights were not appreciated until 70 years later (Schacter, Eich, & Tulving, 1978). Let's look at some people whose work had a more immediate impact.

One of the first true students of memory in a scientific form was **Hermann Ebbinghaus** (1850–1909). He is best known for his 1885 publication *Memory: A Contribution to Experimental Psychology*. This work conveys detailed studies

of memory, using himself as both experimenter and subject. This was a time of psychological research when the study of one's self was more acceptable. Currently, it is viewed as more objective if an experimenter tests another person who knows little to nothing about the experimental hypothesis. There are still some people who test their own memories, but these efforts are rare.

Ebbinghaus tried to study memory in what he considered as pure a form as possible, in the absence of an influence of prior knowledge. To do this, he devised a test stimulus called the **nonsense syllable**, which is a consonant–vowel–consonant trigram that has no clear meaning in language. Nonsense syllables for English include PAB, SER, and NID. Ebbinghaus created and used about 2,300 of these. These nonsense syllables have been used by researchers to study memory for decades and they spent a great deal of effort studying them, even to the point where nonsense syllables were rated for meaningfulness (Glaze, 1928). For example, “BAL” is rated high in meaningfulness (because of “ball”), whereas “XAD” is rated very low.

Ebbinghaus memorized lists of nonsense syllables of various lengths, under various learning conditions, and for various retention intervals before he tested himself. (In some studies he did use some real words on the premise that it would have little effect.) For memory retrieval he would give himself the first nonsense syllable and then try to recall the rest in the list. Using this approach, he was able to discover a wide range of basic principles of human memory that have withstood the test of time, which are covered next. It should be noted that although Ebbinghaus discovered these principles using nonsense syllables, these same patterns are observed with all types of information.

The **learning curve** is the idea that there is a period of time for information to be memorized. It can be affected by a number of things, such as the amount of information to be learned. The learning curve is a negatively accelerated function in which most of the action occurs early on, with smaller and smaller benefits later on, so the largest amount of information is learned in the first segment. In the second, although more is learned, the gain is not as great as during the first. A similar description applies to the third segment, and so on. Furthermore, Ebbinghaus showed that how a person went about learning, in terms of the distribution of practice, influenced how well information was learned. Specifically, memory is better when practice is spread out over time, rather than lumped together—a distinction between what is known as **distributed practice** and **massed practice**.

The **forgetting curve** is the opposite of the learning curve. The forgetting curve, like the learning curve, is a negatively accelerating function. As we'll see in [Chapter 3](#), most of what is forgotten is lost during the initial period. As time

goes on, forgetting continues but at a slower pace. The more time that passes, the slower the rate of forgetting.

Forgetting is the most problematic aspect of memory, and the forgetting curve suggests that we are doomed, sooner or later, to lose all of our memories. However, this is not strictly the case. There is some knowledge that you've had for years and are unlikely to ever forget. This may happen by a process called **overlearning**, in which people continue to study information after perfect recall has been achieved, insulating the memory against forgetting. If there is substantial overlearning, forgetting may be delayed for quite some time, perhaps indefinitely.

When information has been forgotten to the point that nothing can be recalled with accuracy or reliability, it might seem that people must start at square one and repeat all of the previous effort. However, this is not the case. Ebbinghaus found that, after seemingly complete forgetting, subsequent attempts to relearn the information required less effort than the first time. The difference between the amount of effort required on a subsequent and initial learning attempts is called **savings**. The existence of savings is very important. It demonstrates that knowledge that appears to be lost may be residing somewhere in memory. It is no longer consciously accessible but it can still exert an unconscious influence on behavior—in this case, serving as a platform on which to build a new set of consciously available memories.

Another major figure in the study of human memory is **Sir Fredrick Bartlett** (1886–1969). Bartlett was, in some ways, the opposite of Ebbinghaus. Whereas Ebbinghaus was interested in memory independent of prior knowledge, Bartlett was directly interested in how prior knowledge influenced memory. He found that prior knowledge profoundly influences memory. He suggested that memories are often fragmentary and incomplete. When people are remembering, they are reconstructing the information from the bits that they have along with prior knowledge about similar circumstances. This reconstruction is guided by “schemas” (an idea also used by the Gestalt psychologists). Schemas are general world knowledge structures about commonly experienced aspects of life (see [Chapter 9](#)). To illustrate the effects of schemas, Bartlett had people read a story and then later try to recall it anywhere from immediately after they read it to several months or years later. What he found was that memories for the story became more fragmented, and its content was altered to make it more consistent with a stereotypical story.

TRY IT OUT

There are some fundamental characteristics of memory that can be understood even at this early juncture, such as the **forgetting curve**. The aim of this Try It Out section is to assess the forgetting curve. For this task, first create some lists of 20 or so words to use as your materials. When you generate these lists, try to keep the words similar in some way, such as all being from the same class of words (e.g., nouns or verbs), being similar in length (e.g., five to six letters long with two syllables), and so on. If you want, you can try other kinds of items, such as pictures, sentences, odors, or any other kind of materials that may interest you.

When you present the information to people, keep the presentation time constant for each item, such as three to five seconds. What is important here is the amount of time that has passed from when people first learn a list and when they later have their memory tested. A simple, straightforward way to do this is to test people immediately, after one hour, after one day, and after one week, although you can use other retention intervals. This critical thing is to have different periods of time between when you test people.

Try to have at least 12 participants for each period of delay. These can either be different people for each retention interval or the same people, tested on different word lists at the different time delays. If you go with the second option, it is best if people memorize a different list of words for each retention delay, and even better if you separate out the lists and memory test delays. That is, do not give people all of the word lists at once and then test them at different delays. This may confuse them. Instead, you might first give people the first list and then test them immediately. Then, you would give people the second list to learn and then wait an hour to test them. Then, give people the third list of words, and so on.

For the memory test, there are three ways that you can measure memory (see [Chapter 3](#)). They are recall, recognition, and savings. If all goes well, what you should find is that memory for the word lists will decline in a way that shows the greatest rate of forgetting soon after the list is encountered, and a slower rate of forgetting at longer periods of time.

To assess memory using **recall**, have people report all of the items that they can remember by either writing them down on a piece of paper, typing them into a computer, saying them aloud, or whatever works best for you. To score this, count up the number of items from a given list that were correctly reported. Plot the number correct as a function of the amount of time that had elapsed.

To assess memory using **recognition**, give people a series of items and have

them indicate—“yes” or “no”—whether each one was learned earlier. Ideally, half of the items will be ones that they studied earlier, and the other half, called lures, would be similar items that were not studied. This can be done by having people mark “yes” or “no” next to a series of items on a piece of paper, having them respond to flashcards, showing people a series of PowerPoint slides, and so on. To score this, count up the number of studied items that were correctly identified and subtract any incorrect items that a person erroneously said “yes” to (to correct for guessing). Finally, plot the corrected recognition scores as a function of the amount of time that had elapsed.

To assess memory using **savings**, instead of having people study each item for a set period of time, have people repeatedly go over the list until they can recall the entire set from memory. Then, after memorization, wait a given retention period and have people relearn the list until it can be perfectly recalled again. To score this, calculate the difference in the memorization times used initially and after the retention interval. This difference is the savings score. Finally, plot the savings scores as a function of the amount of time that had elapsed.

Another prominent early psychologist was **William James** (1842–1910).¹ Much of his influence comes through his book *The Principles of Psychology* (1890/1950). James was a primary figure in the functionalist movement of early psychology. In terms of memory, James provided descriptions of memory that are remarkably similar to theories in use today. For example, his distinction between primary and secondary memory parallels the distinction between short-term and long-term memory. Similarly, he was one of the first academics to describe memory retrieval problems, such as the tip-of-the-tongue phenomenon (see [Chapter 15](#)), in which a person is not able to remember something, such as someone’s name, but has a strong feeling that retrieval is imminent.

Gestalt Movement

The **Gestalt** movement, primarily advanced by German researchers such as Wolfgang Kohler (1887–1967), Max Wertheimer (1880–1943), and Kurt Koffka (1886–1941), suggested that strictly reductionistic approaches to mental life were incomplete. Instead, one needed the idea that complex mental representations and processes have a quality that is different from the component parts that make them up. This is not to say that the Gestalt psychologists rejected

reductionism. They most certainly did not. Instead, they argued that an understanding of more complex phenomena was important in its own right because it could be qualitatively different. For example, a melody is something that is qualitatively different from the individual notes that make it up, although it is certainly very dependent on them.

One of the ideas of the Gestalt movement that influences thinking about memory is that the whole is *different from* the sum of its parts. This can be seen in the idea that memories are built up of a configuration of simpler elements to take on a new quality. Gestalt psychologists also noted that the observed behavior of people depends on both the context in which they find themselves, as well as a frame of reference. This is reflected in the context effects that are observed in memory, and perspective effects such as the hindsight bias. Moreover, because our context and goals can change, the way we use and organize our memories change according to these demands as well (Danziger, 2008).

A final concept to come out of the Gestalt movement is the idea that mental representations are isomorphic. That is, their mental structure and operation are analogous to the structure and function of information in the world. This idea is clearly seen when spatial memory is discussed (see [Chapter 11](#)). The idea is that the structure of a memory trace reflects the structure of the event, as it would be experienced, although the memory is not as complete. It should be noted that this isomorphism was a functional one. The memory trace functioned “as if” it has the same structure as external events, not that it actually did.

Behaviorism

As we will see in [Chapter 6](#), there are many aspects of memory that operate on a basic and unconscious level. Some of these involve the encoding, storage, and retrieval of relatively simple contingencies that fall under the heading of “conditioning.” This was the domain of the behaviorists. **Behaviorism** is a school of thought that sought to bring greater credibility to psychology as a science. It was a line of thinking that had a strong grip on psychology for much of the early to mid-twentieth century. Part of this effort was to avoid mentalistic constructs because they could not be objectively observed. Although the workings of the mind could not be observed, behavior could be, so much of the experimental work done during the behaviorist era did not directly address issues of memory. However, there were some important insights and discoveries that are relevant here.

Two salient forms of conditioning are classical and operant conditioning.

Classical conditioning is a form of memory that allows one to prepare for contingencies present in the environment, whereas operant conditioning allows one to remember the consequences of one's own actions. Both of these came into the vocabulary of psychology early on in the twentieth century. Classical conditioning was first described by the Russian physiologist Ivan Pavlov (1849–1936), who won the Nobel Prize for his work on digestion. Operant conditioning was first described by an until then little-known American named Edward Thorndike (1874–1949), who discovered these principles starting with his work as a graduate student.

The discovery and study of forms of conditioning are important because for decades they shaped much of the research in learning and memory. There was great interest in studying the principles that guided these forms of learning and the effects they had on behavior. One of the salient qualities of classical and operant conditioning is that one can take these principles pretty far without having to posit much about what is going on mentally. One can just observe the stimulus conditions and the responses produced by an organism.

Despite the general anti-mentalistic view of the behaviorist era, there were some behaviorists who had important insights into issues of memory. For example, Edward Tolman (1886–1959) did a number of studies with rats running through mazes. According to strict behaviorist analyses of maze running, what the rat learns is to make specific turns at specific junctures. Each turn that the rat makes in the maze would be reinforced or not. If this is true, then any change in the maze should cause the rat to need to learn the route all over again. However, Tolman observed that rats adapted to changes very quickly. This led him to suggest that his rats had a mental representation in memory for that spatial location. Tolman called this the “mental map.” The rats could consult this mental map to adapt to the changes in the maze. Thus, working within the behaviorist context, people such as Tolman were able to bring a discussion of memory and mental activity back into mainstream psychology.



PHOTO 1.2 *During the behaviorist era, there was a heavy emphasis on observables, such as the behavior of a rat running a maze, and a de-emphasis on unobservables, such as the memory and thinking that goes on in the mind*

Source: irin717/iStock/Thinkstock

Tolman was a molar behaviorist, although the term he preferred was “purposive behaviorism.” That is, he was interested in larger behaviors as opposed to the more microscopic behaviors that interested many of his colleagues. An example of a molar behavior might be something like getting to the end box of a maze or going to a movie, whereas a microscopic behavior might be an action like “turn left.” This interest in molar behavior can be seen in an approach to memory that takes into account the goals and context of a person in the memory situation.

Verbal Learning

The **verbal learning** tradition existed in the context of a behaviorist psychology and stemmed from Ebbinghaus’s work with nonsense syllables. The term “verbal learning” itself reflects the behaviorism of many of its practitioners, although what was being studied was a form of memory. Because of this context, these studies often had clearly defined stimulus and response components. Memorization was referred to as “attachment of responses to stimuli” and forgetting was “loss of response availability.” (For a summary of verbal learning and its relationship to memory, see Tulving & Madigan, 1970.²) The verbal

learning tradition was a way to study memory during the anti-mentalistic era of behaviorism.

One of the dominant methods in the verbal learning tradition is **paired associate** learning, a paradigm developed by Mary Calkins (1894). In this approach, people memorize pairs of items, often words, letters, or nonsense syllables. An example of a pair would be “BIRD–FANCY.” During testing, people would be presented with the first item of the pair and would be told to produce the second (e.g., “BIRD–?”). The first item served as the stimulus and the second as the response.

There were many variations on this theme. The simple A–B paradigm would present people with a list of paired associates and have them recall the B items in the presence of the A cues. Other paradigms are more complicated, where people must learn a second list of items. If this second list is unrelated to the first, this is an A–B C–D paradigm (easy). An example of this would be learning the pair “BIRD–FANCY” in the first list and “TABLE–ARROW” in the second. If the second list retains the initial cues with the first list, it is an A–B A–D paradigm (hard). An example of this would be learning the pair “BIRD–FANCY” in the first list and “BIRD–ARROW” in the second. An alternative is to have the second list be combinations of the A items with synonyms of the B items, called an A–B A–B’ paradigm (very hard). An example of this would be learning the pair “BIRD–FANCY” in the first list and “BIRD–DRESSY” in the second. Finally, if there are recombinations of the A and B items from the first list, this is an A–B A–Br paradigm (very, very hard). An example of this would be learning the pairs “BIRD–FANCY” and “TABLE–ARROW” in the first list and “BIRD–ARROW” and “TABLE–FANCY” in the second. Often what researchers are assessing is the effects of interference of prior learning on new learning. Issues of interference continue to be of interest and some still use paired associate learning. We’ll see some of these ideas explored in the sections on interference in [Chapter 8](#).

Early Efforts in Neuroscience

Memories are stored in the brain and the brain is a complex and busy place. So where exactly is each memory stored? Is it possible to locate individual memories in the brain? This is the basic question asked by neuropsychologists such as **Carl Lashley** (1890–1958). Lashley (1950) did a series of studies in search of the “engram”—the neural representation of a memory. Lashley first trained rats to run through a maze and then surgically removed part of the rats’ brains. After the rats recovered from the surgery, they were placed back into the

maze. If memories for the maze were localized in one part of the brain, then destroying that part would destroy the memory and the rats would then run the maze just as if they were entering it for the first time. The major outcome of these studies was that, no matter what part of the brain was removed, these rats were able to perform better than control rats that were placed in the maze for the first time. The critical factor was how much tissue had been removed, not where (see [Figure 1.1](#)).³ This led Lashley to conclude that engrams were not localized in one part of the brain but are distributed throughout the cortex. While more recent work has shown that some forms of memory may be localized in different parts of the brain, the general conclusion that many different and distributed parts of the brain are used during memory processing is well supported.

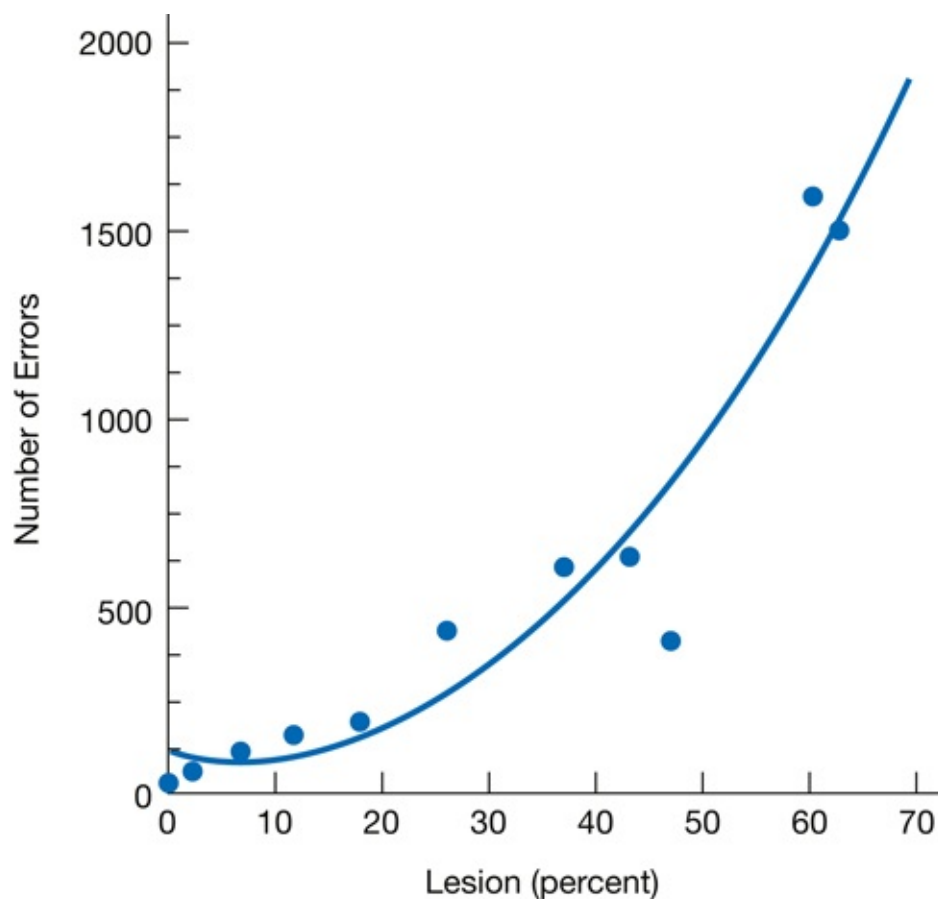


FIGURE 1.1 *Results of Lashley's Experiment with Brain Ablation*

Source: Lashley, K. S. (1950). In search of the engram. *Symposia of the Society for Experimental Biology: Physiological Mechanisms of Animal Behavior* (Vol. 4). New York: Academic Press

In addition to understanding what different parts of the brain do, it is important to understand how the brain works. That is, how do the interconnections among

neurons influence memory? One of the pioneers along this line of research was **Donald Hebb** (1904–1985). Through his classic book *The Organization of Behavior* (1949), Hebb became one of the forerunners of computational neuroscience—the mathematical modeling of brain activity. According to Hebb, memories were encoded in the nervous system in a two-stage process. In the first stage, neural excitation would reverberate around in cell assemblies. A collection of cells that corresponds to a new pattern or idea would be stimulated and this stimulation would continue for some time. In the second stage, the interconnections among the neurons would physically change, with some connections growing stronger. The classic phrase here is “neurons that fire together, wire together.” This is similar to the idea of long-term potentiation, discussed in [Chapter 2](#). It takes some time for memories to move from stage 1 to stage 2. This is why if people suffer a trauma to the brain, such as a blow to the head, they may lose recent memories (see [Chapter 18](#)). In addition, Hebb’s ideas of neural organization and change help lead to the development of computational models of the nervous system, such as the parallel distributed processing (PDP) models, which are discussed in [Chapter 10](#).

The Cognitive Revolution

Over time, psychologists became frustrated with the constraints of behaviorism. There was a desire to study mental activity as mental activity, not as a black box between the input of the stimulus and the output of the response behavior. The **cognitive revolution** of the 1950s and 1960s marked a return of mental states to legitimate study. It made the study of memory palatable once again.

Many people contributed to the cognitive revolution. We focus here on one whose efforts serve as an example of the work and ideas that brought about this change. George Miller (1920–2012) provided a number of important findings for memory research, such as his work on the capacity of short-term memory in his paper “The Magical Number Seven, Plus or Minus Two” (Miller, 1956). This work took the idea of mental processing seriously and demonstrated how it was a limited system, much like a computer’s processing is limited by the amount of memory it has. These studies were some of the first to show that memory could be studied with the methodological rigor that the behaviorists were so fond of.

Miller also showed that how people mentally organized information influences memory. The more highly organized a set of information was, the better the memory. In other words, how information is actively thought about later affects memory. In addition, the knowledge that a person has stored in long-term

memory can influence current memory performance in profound ways. Thus, work by Miller, and people like him, showed that, in order to understand how memory works in the current situation, one must understand how it is structured over the long term.

Stop and Review

The study of memory stretches back to ancient times, with philosophers such as Plato and Aristotle. Other important thinkers to influence thought about memory include St. Augustine, Robert Hooke, and Charles Darwin, as well as the various philosophy of mind figures. The scientific study of human memory began with people such as Hermann Ebbinghaus, Sir Frederick Bartlett, and William James. Current thinking and research is also guided by work of the Gestalt psychologists and the behaviorists. The verbal learning tradition, which emerged out of the behaviorist era, and efforts in neuroscience evolved into our current cognitive science approach to memory.

THE MODAL MODEL OF MEMORY

The standard model of memory, or the **modal model** (Atkinson & Shiffrin, 1968), is a heuristic guide for understanding how memory works. It has successfully limped along for years as a framework for discussing issues about how information is stored over time. This model has four primary components: (1) sensory registers, (2) short-term store, (3) long-term store, and (4) control processes. An outline of the model is shown in [Figure 1.2](#).

The first component, the **sensory registers**, is best thought of as a collection of memory stores. Each of these stores corresponds to a different sensory modality. For example, there is a sensory register for vision, one for audition, one for touch, and so on. The world is full of information that is in a constant state of flux. Our sensory registers allow us to hold on to this information for brief periods of time to determine if it is worthy of further attention. If we did not possess such memory stores, our minds would be constantly locked into only the very current state of affairs. We would not be able to detect patterns that involve very brief memories, such as determining that two frames of a film can be interpreted as continuous movement, or that a sequence of sounds forms a word.

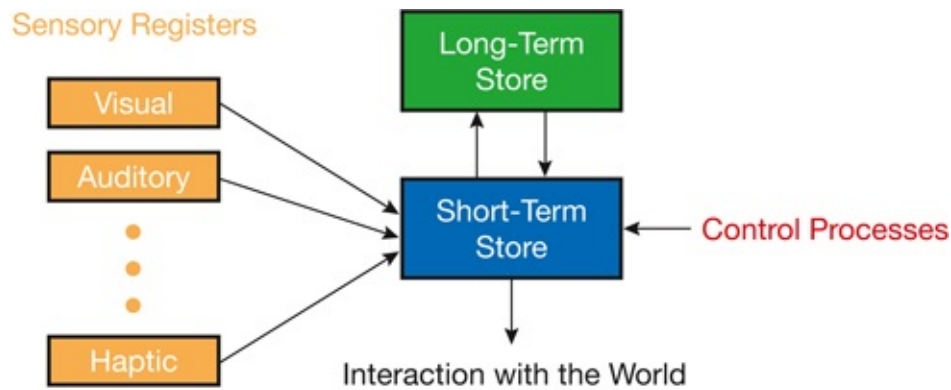


FIGURE 1.2 *The Modal Model of Memory*

Adapted from: Atkinson, R. C., & Shiffrin, R. M. (1968). Human memory: A proposed system and its control processes. *The Psychology of Learning and Motivation*, 2, 8–195

Once information has been attended to, it needs to be kept in the current stream of thought. Because what we are currently thinking about constantly changes, this information needs to be kept available for a short period of time. This **short-term memory** generally retains information for less than a minute if nothing is actively done with it. If consciousness is associated with any part of memory, it would be the information in short-term memory. This is knowledge that is either currently in conscious awareness or just beyond it. Another characteristic of short-term memory is its capacity—the amount of information that can be held in an active state. This amount is humbly small—somewhere on the order of seven items. The topic of the sensory registers and short-term memory are considered in detail in [Chapter 4](#).

The third part of the modal model is the idea that there are **control processes** that manipulate information in short-term memory. This can include rehearsing information, transferring knowledge to and from long-term memory, or perhaps even reasoning. This component of memory makes it an active participant in reality rather than just a passive absorption and retrieval mechanism. The idea that control processes work with knowledge in the service of some goal has led to the idea that short-term memory should be considered more of a working memory system. Issues of working memory are considered in [Chapter 5](#).

The fourth component of memory—the one that interests most people and that much of this text is devoted to—is long-term memory. **Long-term memory** encompasses a wide variety of long-term knowledge and different ways of using that knowledge. Issues of long-term memory are covered extensively in [Chapters 6 through 18](#).

Again, it should be noted that the modal model is a heuristic for thinking about