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8 MEMORY

LEARNING OBJECTIVES

8.1 Explain how visual and auditory sensory memories can be measured and how and why information is represented, maintained, and forgotten over the short term.

8.2 Identify the three types of long-term memories and their roles in remembering, and describe some mnemonic techniques that can aid long-term memory.

8.3 Assess the role of retrieval cues in remembering and explain how schemas aid in reconstructing memories and solving the problems of long-term remembering.

8.4 Explain why forgetting is often adaptive and identify the mechanisms through which forgetting occurs.

8.5 For each of the major sections of the chapter, summarize how our memory systems solve critical problems of behavior and mind.

CHAPTER OUTLINE

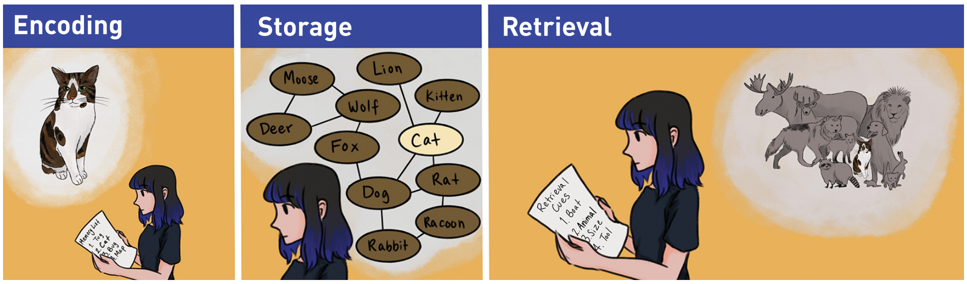
What if the flow of time suddenly fractured and you were forced to relive the same 10 minutes, over and over again, in an endless pattern? Maybe you'd be driving your car or reading a book; it wouldn't matter—at the end of the interval you'd begin again, back at the same fork in the road or the same location on the page. Think about how this might affect you. Perhaps you wouldn't age, but would you be able to maintain any semblance of psychological health?

The answer, of course, depends on your capacity to remember and forget. If your memories remained intact from one day to the next, if you were aware of the endless repetition, life would quickly become unbearable (even if it was a particularly good day). But if your memories were erased before each new 10-minute interval, you'd lack awareness of your hopeless plight; your life, although existing in an abbreviated form, would continue as usual. This type of situation has been depicted in movies, in which the character relives the same day over and over (e.g., *50 First Dates, Groundhog Day*). As you'll see in this chapter, some individuals suffer a similar kind of memory deficit due to an illness or injury that damaged specific areas of their brain.

It's through **memory**—broadly defined as the capacity to preserve and recover information—that concepts like the past and the present gain meaning in our lives. Like learning, memory is not something that can be directly observed. It's an *inferred* capacity, one that psychologists assume must be operating when people act on information that's no longer physically present. To understand how memory works, we need to consider how memories are formed, how memories are maintained over time, and how the stored information is recovered and translated into performance. The processes of **encoding** determine and control how memories are initially acquired. **Storage** controls how memories are maintained. **Retrieval** is the term used to describe how stored memories are recovered and translated into performance. Each of these key psychological processes is illustrated in Figure 8.1.

FIGURE 8.1 ■ Basic Memory Processes

When a person is asked to remember a word such as CAT, how the person thinks about it will affect how that word is encoded into memory (panel 1). CAT might then be stored in long-term memory by activating existing knowledge structures (panel 2). If the person uses the cue ANIMAL to help retrieve the memory of CAT, it might be difficult to pick out the correct response from other animals stored in memory (panel 3).



Illustrated by Sarah Yeh

THE PROBLEMS TO BE SOLVED: WHAT IS MEMORY FOR?

Memory is a highly adaptive feature of our cognitive tool kit. By maintaining and recovering the past, we equip ourselves to better handle the present. We can change our behavior to correct past mistakes, or we can continue to act in ways that have led to past success. But as you'll see in this chapter, memory is far more than simply recovering past events. A world without memory would be devoid of thought and reason. You would never learn; you would never produce spoken language or understand the words of others; your sense of personal history would be lost along with much, if not all, of your personal identity. In this chapter, we focus on the key adaptive problems that memory helps us solve.

Remembering Over the Short Term

It's natural to link memory to the recovery of events that happened hours, days, or weeks ago, but we need to remember over the very short term as well. Consider the interpretation of spoken language. Because speech unfolds one word at a time, it's necessary to remember the early part of a sentence, after it has receded into the past, before you can hope to understand the meaning of the sentence as a whole. Likewise, when we perform most mental tasks, such as solving math problems, certain bits of information must be retained during the ongoing solution process. Try adding 28 and 35 in your head without remembering to carry the 1 (or subtract 2 if you round the 28 up to 30). By establishing short-term memories, we're able to prolong the incoming message, giving us more time to interpret it properly.

Storing Information for the Long Term

To remember information for longer periods, it needs to be learned in a way that promotes lasting storage. Forming a visual image of a to-be-remembered item generally increases its durability in memory. Thinking about the meaning of the item, or relating the item to other material that's already been stored, helps as well. As you already know, practicing retrieval through self-testing is another extremely effective way to remember over the long term. We'll consider these techniques in some detail, and we'll provide more tips to help you improve your ability to remember.

Recovering Information From Cues

What initiates an act of remembering? What causes you to remember your appointment with your academic adviser this afternoon, what you had for breakfast this morning, or that fleeting encounter you had with a stranger yesterday? Most researchers believe that our memories are triggered by other events, or cues, encountered in the environment. When we fail to remember, it's usually because we lack the right retrieval cues. We'll discuss what makes a "good" retrieval cue, and we'll examine how existing knowledge is used to help us reconstruct what happened in the past.

Updating Memory

It's upsetting to forget, but forgetting has very useful properties. Among other things, it prevents us from acting in ways that are no longer appropriate. It's the homework assignment you need to complete *today* that's critical, not the one from yesterday or the week before. It's your *current* address that you need to remember, not the one from a previous apartment or from the home you lived in as a child (although you can probably still remember that address if you lived there your whole childhood). We'll consider the major determinants of forgetting, both the normal kinds and the abnormal forgetting of the type that characterizes amnesia.

REMEMBERING OVER THE SHORT TERM

When information first reaches the senses, we rely on two memory systems to help us prolong the incoming message over the short term. The first, called **sensory memory**, keeps the message in a relatively pure, unanalyzed form. Sensory memories are like fleeting snapshots of the world. The message is represented in accurate detail—as a kind of picture or echo—but the memory usually lasts less than a second. The second system, **short-term memory**, is a limited-capacity "working memory" that we use to hold information after it has been analyzed for periods lasting on the order of a minute or two. Short-term memories are also rapidly forgotten, but they can be maintained for extended periods through internal repetition. Let's take a brief look at each of these systems and consider some of their important properties.

Sensory Memory: The Icon and the Echo

When you watch a movie, you experience a continuous flow of movement across the screen. As you probably know, the film does not contain moving images; it is composed of still pictures presented rapidly in sequence, each separated by a period of darkness. We perceive a continuous world, some researchers believe, partly because the nervous system activity left by one picture lingers for a brief period prior to presentation of the next image. This extended nervous system

The trails of light created by a whirling sparkler are caused by visual sensory memories, which act like still photographs of the perceptual sense.

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activity creates a sensory "memory" that helps to fill the gap, thereby providing a sense of continuous movement.

In vision, the lingering sensory memory trace is called an *icon*, and the sensory memory system that produces and stores icons is known as **iconic memory** (Neisser, 1967). It's relatively easy to demonstrate an icon: Simply twirl a flashlight about in a darkened room, and you will see a trailing edge. You can obtain a similar effect on a dark night by writing your name in the air with a sparkler or a match. These trails of light are not really present in the night air; they arise from the rapidly fading images of iconic memory, which act as still photographs of the world. These images allow the visual sensations to be extended in time so that the brain can more efficiently process the physical message it receives (Coltheart & Coltheart, 2010). In other words, an iconic memory is a short-lived image of a visual sensation (e.g., words on a page, an outdoor scene).

In the auditory system, there is a lingering *echo*, or **echoic memory**. Pure sounds can be held for brief intervals to help auditory perception—echoic memory acts as an echo of sound sensations (e.g., words someone just spoke to us, an abrupt and loud sound). In Chapter 5, you learned how the brain calculates arrival time differences between the ears to help localize sounds. However, to compare arrival times, the first sound must be retained until the second one arrives; echoic memory may help fill the gap. Echoic memory is also widely believed to play a role in language processing, perhaps to help retain exact replicas of sounds during sentence and word processing (Crowder, 1976; Nairne & Neath, 2012).

Measuring Iconic Memory

How can an icon be measured? More than 60 years ago, a graduate student in psychology named George Sperling (1960; also see Averbach & Coriell, 1961) developed a clever procedure for studying the properties of iconic memory. Using an apparatus called a tachistoscope, which presents visual displays for carefully controlled durations (computers were not being used in psychological experiments yet), Sperling showed people arrays of 12 letters arranged in rows. For example:

XLWF

JBOV

KCZR

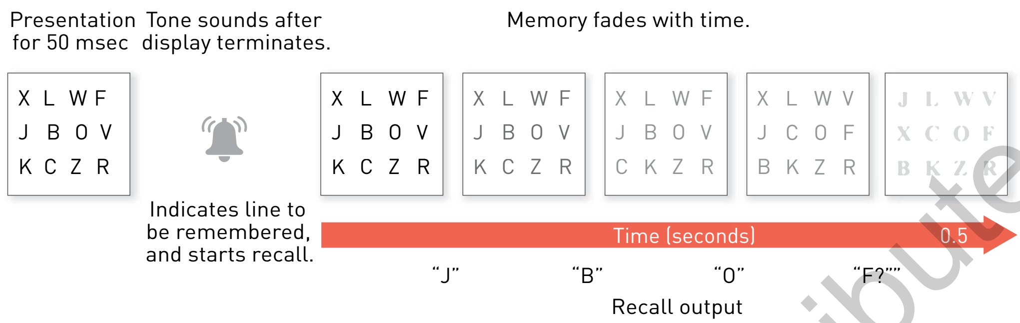
The person's task was simple: Look at the display and then report the letters. Sounds easy, but the presentation time was extremely brief—the display was shown for only about 50 milliseconds (one-twentieth of a second). Across several experiments, Sperling found that people could report only 4 or 5 letters correctly in this task (out of 12). But more important, they claimed to see an image—an icon—of the *entire* display for a brief period after it was removed from view. All 12 of the letters could be seen, the people claimed, but the image faded before all could be reported.

To provide evidence for this rapidly decaying image, or icon, Sperling tried asking people to report only the letters shown in a particular row—but, critically, he didn't tell them which row until after the display was turned off. A high, medium, or low tone was presented immediately after the display, which cued participants to recall just the top, middle, or bottom row (see Figure 8.2). Sperling called this new condition *partial report* because only a part of the display needed to be recalled. Performance was great—people almost always reported the row of letters correctly.

Remember, people heard the tone *after* the display had been turned off. There was no way to predict which row would be cued, so the entire display must have been available in memory for participants to perform so well. Performance improved, Sperling reasoned, because people had enough time to read a single cued row, but not the entire display, before the iconic image had completely faded. In further experiments, he was able to measure how quickly the sensory image was lost by delaying presentation of the tone. He discovered that the fleeting image—the iconic memory—was indeed short-lived; it disappeared in about half a second.

FIGURE 8.2 ■ The Partial Report Technique

After presentation of the display, a tone indicates the row of letters to be recalled. As the participant attempts to recall them, the visual iconic memory fades and becomes less and less accurate. When only part of the display is to be recalled, most of the relevant information can be reported before the image is completely lost.



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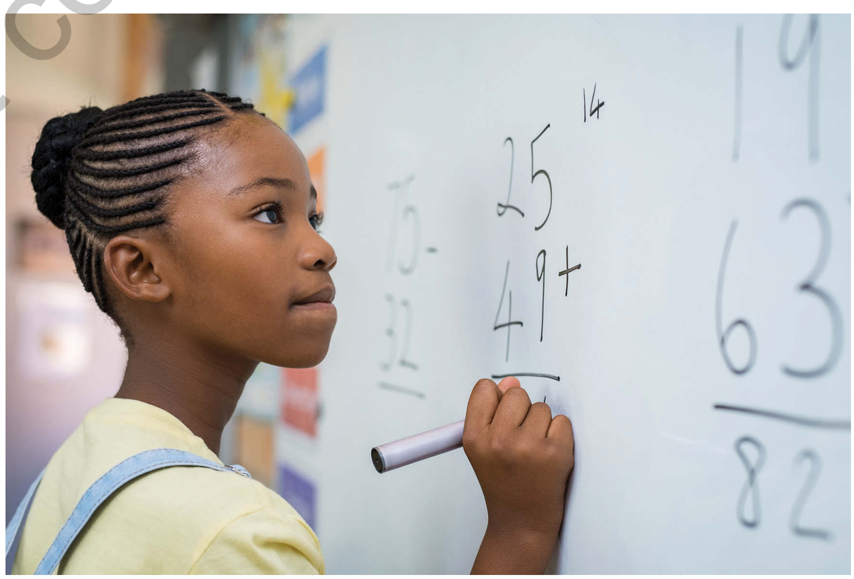
Measuring Echoic Memory

Sensory memories are produced by each of the five senses, but little work has been done on systems other than vision and audition. An experiment by Efron (1970) demonstrates how it's possible to measure the lingering echoic trace, or echo. People were presented with a series of very brief tones, each lasting less than about one-tenth of a second; the task was to adjust a light so that it appeared exactly when each tone ended. Efron discovered that people always thought the tone ended later than it actually did; that is, people reported hearing the tone for a brief period after it had been turned off. Efron argued that this "phantom tone" was caused by a memory—the lingering echo of echoic memory. As in visual sensory memory, auditory sensory memory is believed to last for only a brief period of time—probably less than a second—although in some circumstances it may last longer, perhaps for as long as 5 or 10 seconds (N. Cowan, 1995; Nees, 2016).

Short-Term Memory: Prolonging the Present

The function of sensory memory is to maintain an exact replica of the environmental message, for a very short period, as an aid to perception. *Short-term memory* is the system we use to temporarily store, think about, and reason with information. The term *working memory* is sometimes used because this temporary storage system often acts as a kind of mental workplace, allowing us to store the components of a problem as we work toward a solution (Baddeley, 2017; Nairne, 2002a).



Short-term memory can help us store information we need for everyday tasks such as completing math problems.

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It's useful to keep recently presented information available over the short term. Consider language: It would be hard to understand spoken language, which occurs sequentially (one word at a time), without remembering the first part of a spoken phrase. It would also be difficult to read any kind of text without keeping themes of the passage, or what was presented in the previous sentence, in mind. Short-term memories help us produce and interpret spoken language, remember the task we're currently working on, reason and problem-solve, and even think. In the following sections, we consider some of the properties of short-term memories, including how and why they're forgotten.

The Inner Voice

Unlike sensory memories, short-term memories are not exact copies of the environmental message. When we maintain information over the short term, it is usually in the form of an inner "voice." You can convince yourself by repeating this word—PSYCHOLOGY—silently inside your head. Notice you can repeat the word quickly or slowly, and, if you like, you can even insert internal pauses after each repetition. There's nothing visual about this repetition process; you have recoded, or translated, the visual message PSYCHOLOGY into another form—an inner voice.

This notion of an inner voice is supported by the errors that occur during short-term recall. When recalling over the short term, people invariably make errors that are acoustically based. Mistakes tend to *sound* like correct items even when the stimulus materials have never been presented aloud (Conrad, 1964). For example, suppose you're given five letters to remember—B X R C L—but you make a mistake and misremember the fourth letter. Your error will probably be a letter that sounds like the correct one; you're likely to incorrectly remember something like T or P. Notice that C and T and P all sound alike, but they *look* nothing alike. It's believed that errors tend to be acoustic because people typically recode the original visual input into an inner voice.

Why do we store things over the short term in an inner voice? It's probably because we're often called on to interpret and produce spoken language. It makes sense to think in a way that's compatible with the way we communicate. In fact, there's some evidence to suggest that individuals who are deaf or hearing-impaired, particularly those who communicate with American Sign Language, do not rely on an inner voice to the same extent as people with normal hearing; they sometimes encode information in a form that's compatible with their normal language format (Hall & Bavelier, 2011).

The Inner Eye

We usually use our inner voice to store short-term memories, but we can use other formats. For example, sometimes we use visual images. To illustrate, close your eyes and count the number of windows in your house or apartment. Did you perform this task by visualizing the rooms, one by one, and counting the number of windows you "saw"? Now try forming a visual image of a rabbit standing next to an elephant. Does the rabbit in your image have whiskers? If I measure your reaction time, it turns out that you'll answer a question like this more quickly if you imagine the rabbit standing next to a rat instead of next to an elephant (Kosslyn, 1983). This is exactly the kind of result we'd expect if you were looking at an actual picture—the larger the object is in the picture, the easier it is to "see."

Experiments have shown that the imagery produced by the "inner eye" may rely on the same brain mechanisms as normal visual perception. Neuroimaging techniques reveal that imagery and perception activate many of the same regions in the brain (Cichy et al., 2012). Other studies have found that people have trouble storing a visual image in their head while they're also performing a visually based tracking task, such as finding locations on a map (Baddeley & Lieberman, 1980). There are even patients with brain damage who report corresponding impairments in both imagery and visual perception. For example, some patients whose brain damage has caused them to lose their color vision also have difficulty forming a colorful visual image. Thus, there appears to be an important link between the brain systems involved in perception and those involved in mental imagery.

Short-Term Forgetting

Have you ever had trouble remembering something (e.g., what the instructor said during a lecture) long enough to write it down or type it into your laptop? It's possible to prolong short-term memories indefinitely by engaging in **rehearsal**, which is the process of internal repetition, assuming that you have the time and resources to continue the rehearsal process. (Think about the word *rehearsal* as "re-hear-sal," as if listening to the inner voice.) Without rehearsal, however, short-term memories are quickly forgotten (Atkinson & Shiffrin, 1968). In an early investigation of short-term forgetting, Lloyd and Margaret Peterson (1959) asked students to recall short lists of three letters (such as CLX) after delays that ranged from 3 to 18 seconds. The task sounds easy—remembering three letters for less than half a minute—but the experiment had an unusual feature: No one was allowed to rehearse the letters during the delay interval; instead, the students were asked to count backward by threes aloud until a recall signal appeared. You can try this experiment for yourself: Ask someone to read you three letters, then try immediately counting backward by threes from the number 832. Finally, have your friend signal you to recall after about 10 to 20 seconds. Under these conditions, you'll probably find that you forget the letters relatively quickly (if the first trial seems easy, try a few more with different letters). In the Petersons' experiment, the students were reduced to guessing after about 10 to 15 seconds of counting backward (see Figure 8.3).

FIGURE 8.3 ■ The Peterson Distractor Test

On each trial, people were asked to recall three letters in correct order, after counting backward aloud for 3 to 18 seconds. The longer the participants counted, the less likely they were to recall the letters correctly.

Input		Distraction Interval, Counting Backward	Recall
Trial 1	CLX	". . . 391-388"	"C-L-X"
Trial 2	FVR	". . . 476-473-470"	"F-V-R"
Trial 3	ZQW	". . . 582-579-576-573"	"Z-W-Q?"
Trial 4	LBC	". . . 267-264-261-258-255"	"L-B-"
Trial 5	KJX	". . . 941-938-935-932-929-926"	"K-?-?"
Trial 6	MDW	". . . 747-744-741-739-736-733-730"	"?-?-?"
		0 3 6 9 12 15 18 Time (sec)	

Why is information forgotten so rapidly without rehearsal? Some researchers believe that short-term memories are lost spontaneously over time, through a process called *decay*, unless those memories are kept active through rehearsal (Barrouillet et al., 2012). Decay also explains the rapid forgetting of sensory memories. Other researchers believe that short-term forgetting is caused primarily by *interference* from new information or because people confuse current memories with past memories (e.g., Oberauer et al., 2016). A third possibility is that decay and interference operate together to produce information loss. We'll return to the question of what causes forgetting later in the chapter.

Short-Term Memory Capacity

Another characteristic of short-term memory is its limited capacity: We can only remember a small amount of information over the short term. Research has shown that short-term **memory span**—which is defined as the number of items a person can recall in the exact order of presentation on half of the tested memory trials—is typically about seven, plus or minus two items. In other words, short-term memory span ranges between five and nine items (G. A. Miller, 1956). It's easy to remember a list of four items but quite difficult to remember a list of eight or nine items (which is one of the reasons telephone numbers are seven digits long).

Most psychologists believe that the capacity of short-term memory is limited, in part, because it takes time to execute the process of rehearsal. To illustrate, imagine you're asked to remember a relatively long list of letters arranged this way:

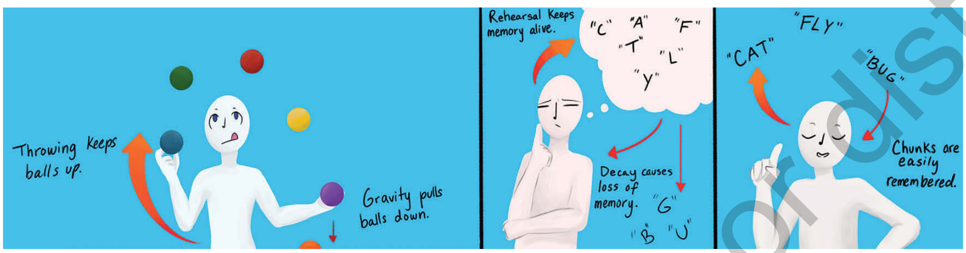
CA TFL YBU G

First, try reading this list aloud, from C to G. You'll find that several seconds elapse from start to finish. Now imagine cycling through the list with your inner voice as you prepare for short-term recall. It turns out that the C to G cycling takes a similar amount of time inside your head (Landauer, 1962).

Remember, however, that items stored in short-term memory are forgotten in a matter of seconds, so the first part of the list tends to be forgotten during execution of the last. By the time you've finished with the last letter and returned to the beginning of the list, the early items have already been lost from memory. You can think about this relationship between forgetting and rehearsal as roughly similar to juggling (see Figure 8.4). To juggle successfully, you need to win the battle against gravity. You throw the dinner plates up, and gravity pulls them down. To prevent one of the plates from crashing, it's necessary to catch and toss it back up before gravity runs it into the ground. Similarly, you need to return to the rapidly fading short-term memory trace and reactivate it through rehearsal before the "forces" of forgetting win out. It's a race between two opposing forces—rehearsal and forgetting.

FIGURE 8.4 ■ The Capacity of Short-Term Memory

The amount of information that can be stored in short-term memory depends on rehearsal, which you can think of as roughly analogous to juggling. You return to each rapidly fading short-term memory trace and reactivate it through rehearsal before it is permanently forgotten. Chunking the material makes it easier to rehearse and therefore remember the information.



Illustrated by Sarah Yeh

People differ in their ability to rehearse and maintain short-term memories. These individual differences are related to our ability to allocate attention to a task, such as rehearsal, especially when we have more than one thing to do at a time. Some people are quite good at rehearsing information while performing another task—for example, remembering a coupon code while searching the internet. It turns out that the ability to keep multiple things available in short-term memory at the same time predicts performance on higher-order cognitive tasks, such as reasoning, or even your score on an intelligence test (Fukada et al., 2010). It is also the case that some clinical conditions, such as attention-deficit disorder and schizophrenia, are associated with problems in the ability to use short-term memory effectively (S. K. Hill et al., 2010).

Chunking

As a general rule, memory span is roughly equal to the amount of material you can internally rehearse in about two seconds (which usually turns out to be about seven plus or minus two items). To improve your ability to remember over the short term, then, it's best to figure out a way to rehearse a lot of information in a short amount of time. One effective strategy is **chunking**, which involves rearranging the incoming information into meaningful or familiar patterns, called chunks. Remember that long list of letters presented earlier (CA TFL YBU G)? Perhaps you saw that the same list could be slightly rearranged:

CAT FLY BUG

Forming the letters into words drastically reduces the time it takes to repeat the list internally (try saying CAT FLY BUG over and over internally). In addition, once you remember a chunk, it's easy to recall the letters—in most cases, words are great storage devices for remembering sequences of letters. Of course, the trick lies in finding meaningful chunks in what can appear to be a meaningless jumble of information.

The ability to create meaningful chunks often depends on how much you know about the material that needs to be remembered. Expert chess players can re-create most of the positions on a chessboard after only a brief glance—as long as a meaningful game is in progress (Chase & Simon, 1973). They recognize familiar attack or defense patterns in the game, which allows them to create easy-to-rehearse chunks of position information. Similar results are found when electronics experts are asked to remember complex circuit board diagrams (Egan & Schwartz, 1979). In both cases, if the materials are arranged in a more or less random fashion (e.g., the chess pieces are simply scattered about the board), the skilled retention vanishes, and memory reverts to normal levels.

The Working Memory Model

We've focused on the characteristics of short-term memories—how they're stored and forgotten—but we haven't discussed the "system" that controls memory over the short term. Unfortunately, memory researchers still don't completely agree about the mechanisms that enable us to remember over the short term. Some psychologists believe that memory over the short term is controlled by the same processes that control memory over the long term (Melton, 1963; Nairne, 2002a). But most psychologists assume we have special equipment for short-term memory because of its importance in language and thought. The most popular account of the short-term memory system is the *working memory model* developed originally by Baddeley and Hitch (1974) and elaborated on more recently by Baddeley (2007, 2017).

In the working memory model, several distinct mechanisms are important for short-term retention. First, the temporary storage of acoustic and verbal information is controlled by the *phonological loop*. The phonological loop is the structure we use to temporarily store verbal information and engage in repetitive rehearsal—it corresponds to the inner voice and is believed to play a critical role in language (Baddeley et al., 1998). The short-term retention and processing of visual and spatial information is controlled by a different system—the *visuospatial sketchpad*. If you try to count the number of windows in your house by moving through it in your mind's eye, you are probably involving the visuospatial sketchpad. Finally, Baddeley and Hitch (1974) propose that a *central executive* controls and allocates how processing is divided across the loop and the sketchpad. The central executive determines when the loop or sketchpad will be used and coordinates its actions.

One reason the working memory model is popular among memory researchers is that it helps explain the effects of certain types of brain damage. There are patients, for example, who seem to lose specific verbal skills, such as the ability to learn new words in an unfamiliar language. Other patients retain their language skills but have difficulties with memory for spatial or visual information (Baddeley, 2000, 2007). These results suggest that we have separate systems controlling verbal and visual storage, just as the working memory model proposes. Neuroimaging techniques also show that different areas of the brain are active when we remember spatial and nonspatial information (D'Esposito & Postle, 2015; Jonides et al., 2008).

KNOWLEDGE CHECK 8.1

Now test your knowledge about remembering over the short term by deciding whether each of the following statements best describes sensory memory or short-term memory. (You will find the answers in the Appendix.)

1. Information is forgotten in less than a second: ___
2. Information is stored as a virtually exact copy of the external message: ___
3. Information can be stored indefinitely through the process of rehearsal: ___
4. The system measured through Sperling's partial report procedure: ___
5. Recall errors tend to sound like the correct item even when the item is presented visually: ___
6. May help us calculate message arrival time differences between the two ears: ___
7. Span is roughly equal to the amount of material that you can say to yourself in two seconds: ___
8. Capacity is improved through chunking: ___

STORING INFORMATION FOR THE LONG TERM

Long-term memory is the system we use to maintain information for extended periods. When you remember the name of your fifth-grade teacher or the correct route to class, you're using your long-term memory. Most psychologists believe that the capacity of long-term memory is effectively unlimited. There are no limits to what we can potentially remember, but not everything we experience gets stored. We also don't necessarily store information in a way that makes it easy to remember. To achieve effective long-term storage, it's necessary to *encode* the experience in a way that makes it easy to *retrieve*. We'll consider momentarily the kinds of encoding activities that lead to effective long-term storage, but first let's briefly consider the general kinds of information that are stored.

What Is Stored in Long-Term Memory?

Stop for a moment and think about your first kiss. The recollection (assuming you can remember your first kiss) is likely filled with warmth, intimacy, and perhaps embarrassment. Do you remember the person's name? The situation? The year? Memories that tap some moment from our personal past are called **episodic memories**—they consist of the events, or episodes, that happened to us personally. Most experimental research on memory tests episodic memory because people typically are asked to remember information from an earlier point in the experiment. The task is to remember an *event*, such as a word list, that forms a part of the personal history of the participant.

Some psychologists believe that episodic memory is a uniquely human quality (Tulving, 2002). Other animals show memory, in the sense that they can act on the basis of information that's no longer present (such as remembering the location of food), but they lack the ability to mentally travel backward in time and "relive" prior experiences. They live only in the present and show no awareness of the past. Interestingly, some forms of brain damage produce a similar effect in humans. Such patients appear normal in most respects—they can read and write normally, solve problems, and even play chess—but they lack the ability to remember any events or circumstances from their personal past (M. A. Wheeler & McMillan, 2001).

Now think of a city in Europe that's famous for its fashion and fine wine. A correct response is *Paris*, but did you "remember" or "know" the answer? What about the square root of 9 or the capital city of

It is difficult to teach skills associated with procedural memory because such memories tend to be inaccessible.

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the United States? These are certainly memories, in the sense that you have preserved and recovered information from the past, but "remembering" these answers feels vastly different from remembering your first kiss. When you reveal what you know about the world, but make no reference whatsoever to a particular episode from your past, you're using **semantic memory** (*semantic* refers to "meaning"). It's through semantic memory that we store facts and remember the rules we need to know to adapt effectively in the world.

Finally, think about how to tie your shoes, drive a car, or ride a bike. The knowledge about how to *do* things is called **procedural memory**. Most skills, including athletic ability, rely on procedural memories. Procedural memories differ from episodic and semantic memories in a fundamental way: They rarely produce any conscious experience of "remembering." Most people have a difficult time consciously reporting how to tie their shoes or ride a bike. They can do these things, but it's extremely difficult to put the knowledge into words. Procedural memories are among the simplest of all memories to recover, but they are among the most difficult for psychologists to study—they seem to be inaccessible to conscious awareness (Tulving, 1983). For a summary of these memory types—episodic, semantic, and procedural—see Concept Review 8.1.

CONCEPT REVIEW 8.1
VARIETIES OF LONG-TERM MEMORY

Type of Memory	Description	Example
Episodic	Memories that recall a personal moment from our past	Wanda, the mail carrier, remembers that yesterday 10 inches of snow fell, making her job very difficult.
Semantic	Knowledge about the world, with no specific reference to a particular past episode	Wanda knows that mailing a letter first-class costs 55 cents; she also knows that it costs more to send something by express mail.
Procedural	Knowledge about *how* to do something	Wanda drives the streets of her mail route effortlessly, without really thinking about it.

Elaboration: Connecting Material to Existing Knowledge

Now let's turn to long-term episodic memory. What's the best way to remember something over the long term? As a general rule, if you want a lasting memory, relate what you want to remember to what you already know. There's a vast storehouse of information in the brain, and memory works best when you make use of it. When you actively relate new information to the already-stored content of long-term memory, the process is called **elaboration**. Elaboration works for two reasons: First, it helps establish routes to remembering—that is, retrieval "cues" that ease later recovery. Second, elaboration creates a distinctive memory record that stands out and is easy to identify. Elaboration comes in many forms, as the following sections demonstrate.

Think About Meaning

One of the easiest ways to promote elaboration is to think about the *meaning* of the information you want to remember. In an experiment by Craik and Tulving (1975), people were asked questions about single words such as MOUSE. In one condition, the task required everyone to make judgments about the sound of the word (e.g., does the word rhyme with HOUSE?); in another condition, people were required to think about the meaning of the word (e.g., is a MOUSE a type of animal?). Much better memory was obtained in this second condition. Thinking about meaning, rather than sound, leads to richer and more elaborate connections between events and other things in memory. The deeper and more elaborative the processing, the more likely that memory will improve (Craik & Lockhart, 1972).

Notice Relationships

You can also use your existing knowledge to look for relationships among the things that need to be remembered. Suppose you're asked to remember the following list of words:

NOTES PENCIL AIRPODS LAPTOP MUSIC COFFEE

If you think about what the words mean and you look for properties they have in common—perhaps things that you would take to a study session or a lecture—you're engaging in a form of elaboration called *relational processing*. Relational processing works because you are embellishing, or adding to, the input. If you're trying to remember the word PENCIL and you relate the word to an involved sequence of events, there are likely to be lots of cues that will remind you of the correct response at a later time. Thinking about music, notes, drinking coffee—any of these can lead to the correct recall of PENCIL.

Notice Differences

You should also think about how the material you want to remember is different from other information in long-term memory. If you simply encode PENCIL as a writing tool, you might incorrectly recall things like PEN, CHALK, or even CRAYON at a later time. Instead, specify the particular event in detail—we're talking about a yellow, number 2 pencil, not a crayon—so the memory record becomes unique. Unique memory records are remembered better because they stand out—they're easier to distinguish from related, but not appropriate, material in memory.

Elaboration tends to produce unique memory records—referred to as **distinctiveness**. When you compare to-be-remembered information to other things in memory, noting similarities and differences, you encode how that information both shares properties with other information (relational processing) and is unique or different (distinctive processing). This leads to lots of retrieval cues that will help you remember the encoded material. Generally, if you want to remember something particularly well, you should concentrate on encoding both item similarities and item differences (R. R. Hunt & McDaniel, 1993).

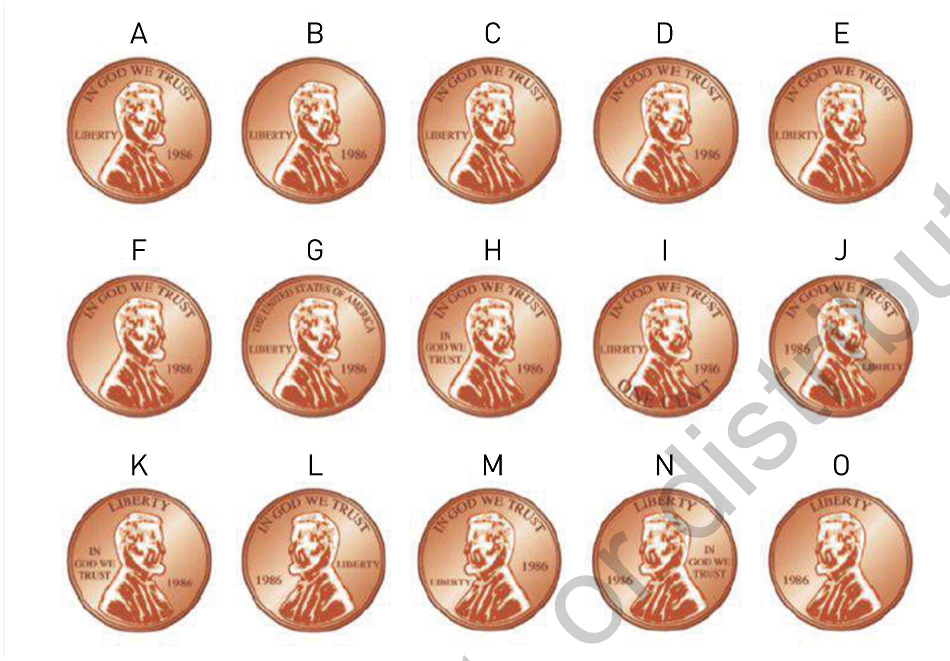
Form Mental Pictures

Another way to produce an elaborate memory record is to form a visual image of the material when it's first presented. If you're trying to remember COFFEE, try forming a mental picture of a steaming hot, freshly brewed cup. Forming mental pictures is an effective memory strategy because it naturally leads to elaborate, rich encodings. Mental pictures require you to think about the details of the material, and these details create a distinctive memory record. As you'll see later, many memory improvement techniques, called mnemonic devices, rely importantly on the use of **visual imagery**.

Visual imagery leads to excellent memory, but the memories themselves are not photographic (as you might assume)—instead, they're surprisingly abstract, and important details are often missing or inaccurate. To demonstrate, try forming a visual image of a penny or a quarter (or a coin in a monetary system you are very familiar with). You've seen coins many times, so this should be a fairly easy task. Now try to reproduce the image on paper—simply draw the image depicted on the coin, which direction it is facing, and so on. Your performance is apt to be mediocre at best. People are simply unable to reproduce the main features of a coin very accurately, despite the strong belief that they can see an accurate representation in their head. In fact, it's even difficult for people to recognize the correct coin when it is presented along with incorrect versions. For a display like the one shown in Figure 8.5, fewer than half of the participants pick out the right penny (Nickerson & Adams, 1979). Certainly, if you were looking at a coin, you would be able to trace the features accurately, so the image we form isn't necessarily an accurate representation of physical reality. This in no way detracts from the power of imagery on memory, however. We may not store exact pictures in our head, but the records produced from imagery are among the easiest to retrieve.

FIGURE 8.5 ■ Can You Recognize a Penny?

We may think we can form an accurate mental image of a penny, but it isn't easy to pick a true penny from a group of fake ones. Can you find the real penny in this display?



Reprinted from "Long-Term Memory for a Common Object" by R. S. Nickerson and M. J. Adams in *Cognitive Psychology,* Volume 11, 287–307. Copyright 1979, with permission from Elsevier.

Space Your Repetitions

Elaborate memory traces can also be achieved through repetition: If information is presented more than once, it will tend to be remembered better. The fact that repetition improves memory is not very surprising, but it might surprise you to learn that repetition alone is not what leads to better memory. It's possible to present an item lots of times without improving memory—what's necessary is that you use each repetition as an opportunity to encode the material in an elaborate and distinctive manner. If you think about the material in exactly the same way every time it's presented, your memory won't improve very much.

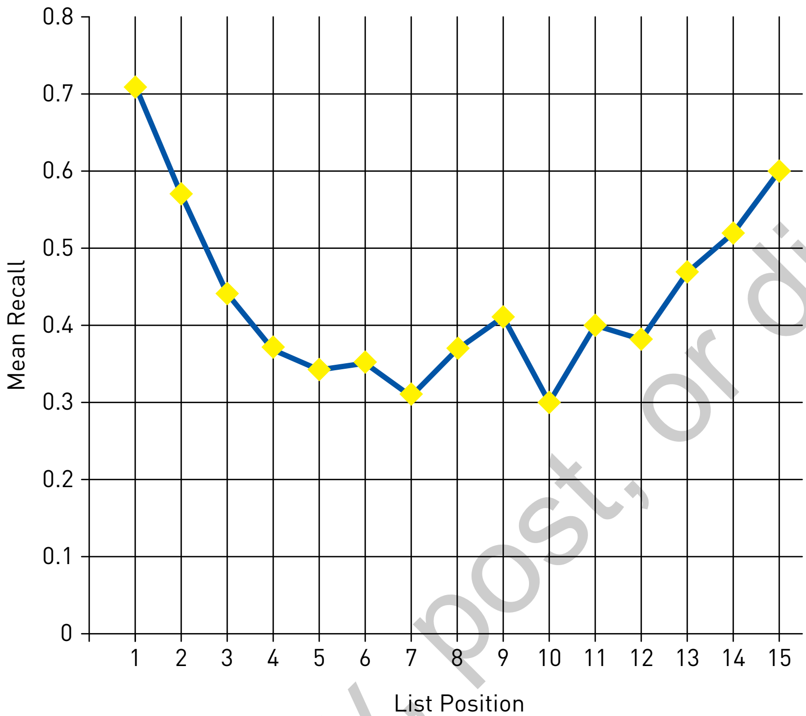
How the repetitions are spaced is another important factor. Your memory will be better if you distribute the repetitions—that is, if you insert other events (or time) between each occurrence. This is called **distributed practice**. It means that all-night cram sessions where you read the same chapter over and over again are not very effective study procedures. It's better to study a little psychology, do something else, and then return to your psychology. Why does distributed practice lead to the best memory? Again, what matters to memory is how you process the material when it's presented. If you use massed practice—where you simply reread the same material over and over again without a break—you're likely to think about the material in exactly the same way every time it's presented. If you insert a break between presentations, when you see the material again there's a better chance that you'll notice something new or different. Distributed practice leads to memory records that are more elaborate and distinctive.

Consider Sequence Position

If you have to remember a set of items, such as a list of grocery items, you'll tend to remember the items from the beginning and the end of the sequence best. This pattern is shown in Figure 8.6, which plots how well items are recalled as a function of their temporal, or serial, position in a list (this graph is often called a serial position curve). The improved memory for items at the start of the list is called the **primacy effect**; the end-of-the-list advantage is called the **recency effect**. Memory researchers believe that primacy and recency effects arise because items that occur at the beginning and end of a sequence are more naturally distinctive in memory and are therefore easier to rehearse and/or to recall (Surprenant & Neath, 2009). Practically, then, if you're trying to remember a list, put the most important things at the beginning and the end of the list.

FIGURE 8.6 ■ The Serial Position Curve

When asked to recall a list of items, our performance often depends on the temporal, or serial, position of the entries in the list. Items at the beginning of the list are remembered relatively well—the primacy effect—and so are items at the end of the list—the recency effect.



Test Yourself

Finally, you've been getting advice about the importance of practicing retrieval throughout this book. When you test yourself, the act of retrieving the information makes that information more memorable. No one is certain exactly why the benefit occurs, but it is one of the strongest ways to produce lasting long-term memory (Roediger & Karpicke, 2018). One popular account is that testing leads to elaboration; during retrieval, but not reading, we generate cues that will remind us of the tested information. Think about it: When you study something, it's right in front of you—you don't need to generate reminder "cues." But when you're required to produce the information from memory, which you have to do when you test yourself, you're on the lookout for hints or clues that will remind you of the answer later on. The act of retrieval helps establish effective retrieval routes, which is a form of elaboration (Pyc & Rawson, 2010). It's also been suggested that correctly remembering the studied information during retrieval practice strengthens the original memory trace made during encoding (Finn & Roediger, 2011). Studies looking at brain activity during retrieval practice suggest that both of these accounts—elaboration and memory strengthening—are responsible for the memory advantage produced by retrieval practice (X. L. Liu et al., 2018).

Mnemonic Devices

Mnemonic devices (*mnemonic* means "pertaining to memory") are special mental tricks developed thousands of years ago as memory aids (Yates, 1966). They're worth discussing because they're relatively easy to use and they have lots of practical applications—in fact, virtually all "how to" memory books rely entirely on these techniques. Professional memorizers, including those who compete in national and international memory contests (the memory "Olympics"), all use versions of these techniques (Foer, 2011).

One of the oldest mnemonic devices is the **method of loci** (*loci* is Latin for "places"). Like most mnemonic devices, the method of loci relies on visual imagery. You start by choosing a well-known place or location—sometimes called a "memory palace"—that's easy to access and remember. A good example might be your house or a route you take to school. In your mind, you then place the material that you want to remember—suppose it's a list of errands—at various locations along the path or within the location. It's important to form a visual image of each memory item and to link the image to a specific location. If you wanted to remember to pay the gas bill, you could form a mental picture of a large check made out to the gas company and place it in the first location on your path (such as the entry hall in your house).

Depending on the size of your pathway, you can store a relatively large amount of material using this method. At the end of encoding, you might have 15 errands stored. Overdue library books could be linked to the living room sofa, clean shirts encased in plastic could be draped across the kitchen counter, or big bags of dog food could be associated with a dog on the television screen (see Figure 8.7).

FIGURE 8.7 ■ The Method of Loci

To-be-remembered items are mentally placed in various locations along a familiar path. They should now be remembered easily because visual imagery promotes an elaborate memory trace and because the stored locations are easy to access.

Illustrated by Sarah Yeh

To recover the material later, all you need to do is walk along the pathway in your mind, "looking" in the different locations for the objects you've stored. The method of loci is an effective memory aid because it forces you to use imagery—creating an elaborate and distinctive record—and the stored records are easy to recover because the storage locations are easy to access.

The **peg-word method** resembles the method of loci in that it requires you to link material to specific memory cues, but the cues are usually words rather than mental pathways. One easy technique is to pick "peg words" that rhyme with numbers: For instance, one is a *bun*, two is a *shoe*, three is a *tree*, and so forth. This makes the pegs easy to remember and access. You then form an image linking the to-be-remembered material with each of the pegs. You might picture your overdue library books inside a hamburger bun, a bag of dog food sitting inside a shoe, or some clean shirts hanging from a tree. To recover the memory records, you would simply start counting, and the peg word should lead you to the image of the to-be-remembered errand. One is a bun—return books; two is a shoe—buy dog food; three is a tree—pick up shirts.

An alternate version of the peg-word method, called the *linkword system*, has been used successfully to assist in learning foreign language vocabulary (Wyra & Lawson, 2018). Suppose you want to remember the French word for rabbit (*lapin*). While studying, think of an English word that sounds like the French word; perhaps the word *lap* would do for *lapin*. Next, think about the meaning of the French word and try to form a visual image of the result linked to the English word. For example, you might imagine a white furry rabbit sitting in someone's lap. When the word *lapin* appears later on a test, the English word will serve as an effective cue for bringing forth a remembered image of the rabbit (*lap* acts as a kind of peg word for *rabbit*). This method has been shown to produce nearly a doubling of the rate of learning for vocabulary words (Raugh & Atkinson, 1975). Although mnemonics are useful for remembering specific types of information, using mnemonics will not improve your memory abilities overall. But the principles underlying these techniques do tell us a lot about how memory works, and that knowledge can help us determine how best to encode information we want to remember.

Remembering With a Stone-Age Brain

The fact that forming a visual image is an effective way to remember shouldn't surprise you too much. After all, we rely heavily on our visual system to navigate and understand our world, so it makes sense that memory, too, relies to some extent on visual imagery (Paivio, 2007). Most cognitive processes, including memory, evolved to help us solve particular problems, and bear the "footprints" of ancestral selection pressures. For example, if people are asked to think about material in terms of its potential survival value, they remember that material particularly well (Nairne et al., 2019). We also tend to remember living things (animates) better than nonliving things (inanimates), presumably because animates are more relevant to our ability to survive and reproduce (Nairne et al., 2017).

In addition, we are likely to form rich records of the circumstances surrounding emotionally significant and surprising events that we hear about (Hirst & Phelps, 2016). So-called **flashbulb memories** have been reported for lots of events—for example, first learning of the election of President Barack Obama, news of the Sandy Hook elementary school shooting, and, most recently, learning of the shutdowns related to COVID-19. People who experience flashbulb memories are convinced they can remember exactly what they were doing when the event occurred. Playing in school, watching television, talking on the phone—whatever the circumstance, people report vivid details about the events surrounding their first exposure to the news. Do you remember what you were doing when you first heard about the March 11, 2011, earthquake and tsunami and subsequent nuclear disaster in Japan? How about the multiple terrorist attacks in Paris on November 13, 2015? Or how about the storming of the U.S. capitol building on January 6, 2021?

Surprisingly, flashbulb memories are often inaccurate. Many U.S. adults have flashbulb memories for when they heard about the September 11, 2001, terrorist attacks. The consistency and confidence of these memories were examined in a study by Talarico and Rubin (2003). The day after the attacks, they asked students at Duke University to report details of where they were when they heard about the attacks. The researchers also asked the students how confident they were that these details were accurate. The students were then asked to report the details again at a second testing that occurred 7 days, 42 days, or 2,224 days after the first testing. The results showed that consistency of the reported details declined as the time from the event increased. However, confidence in the accuracy of the memories did not decline over time. In other words, the students thought they were remembering things accurately, but the data proved otherwise. The fact that their memories were poor suggests that the psychological experience of flashbulb memories—that is, the strong conviction that one's memories are accurate—may be related more to the emotionality of the original experience than to the presence of a rich and elaborative memory record. In fact, research suggests that flashbulb memories are strongest (although not necessarily more accurate) for personally significant events (i.e., the events to which we have the strongest emotional connection; Talarico & Rubin, 2018).

One reason flashbulb memories tend to be inaccurate is that we often incorporate later experiences into our original memories. When something shocking happens, we talk about it a lot, see footage of the event on the news, and hear other people analyze how and why it happened. The events of September 11, 2001, are a good example. When President George W. Bush was asked about his memory for the events some months later, he remembered having seen footage of the first plane hitting

Many adults in the United States have strong flashbulb memories for when and how they heard about the September 11, 2001, terrorist attacks.

Stacy Walsh Rosenstock / Alamy Stock Photo

the tower before he learned about the crash of the second plane. At the time, of course, no footage was available for viewing, so his memory of having seen the first plane attack was simply wrong. This led to some conspiracy theories on the internet—"Bush films his own attack on the World Trade Center"—but a more reasonable explanation is that he simply mistakenly incorporated a later memory (viewing the footage) into his memory for the original event (Greenberg, 2004).

It's important to remember, though, that just because flashbulb memories are sometimes inaccurate doesn't mean they aren't useful and adaptive. We don't necessarily want to remember the past exactly, because the past can never happen again in exactly the same way. Instead, we want to use the past, in combination with the present, to decide on an appropriate action. As you'll see in the next section, remembering often involves reconstructing the past rather than remembering it exactly.

KNOWLEDGE CHECK 8.2

Now test your knowledge of how information is stored over the long term by answering the following questions. (You will find the answers in the Appendix.)

1. For each of the following, decide whether the relevant memory is episodic, semantic, or procedural.
   a. The capital city of Texas is Austin: ______
   b. Breakfast yesterday was ham and eggs: ______

c. My mother's maiden name is Hudlow: ______
d. Executing a perfect golf swing: ______
e. Tying your shoelaces: ______

2. Your little brother Eddie needs to learn a long list of vocabulary words for school tomorrow. Which of the following represents the best advice for improving his memory?
 a. Say the words aloud as many times as possible.
 b. Write down the words as many times as possible.
 c. Form a visual image of each word.
 d. Spend more time studying words at the beginning and end of the list.

3. For each of the following, decide which term best applies. Choose from *distinctiveness, distributed practice, elaboration, method of loci*, and *peg-word technique*.
 a. Visualize each of the items sitting in a location along a pathway: ______
 b. Notice how each of the items is different from other things in memory: ______
 c. Form connections among each of the items to be remembered: ______
 d. Form images linking items to specific cues: ______
 e. Engage in relational processing of the to-be-remembered material: ______

RECOVERING INFORMATION FROM CUES

Can you still remember the memory list from a few pages back? You know, the one based on things you might take to a morning lecture class? If you remembered the items, such as PENCIL, LAPTOP, and COFFEE, it's probably because you were able to use the common theme—things you might take to a lecture—as a *cue* to help you remember. Psychologists believe that *retrieval*, the process of recovering previously stored memories, is guided primarily by cues, called *retrieval cues*, that are either generated internally (thinking of the lecture scene helps you remember PENCIL) or present in the environment (a string tied around your finger). Retrieval cues not only initiate an act of remembering; they also help shape what is remembered (or misremembered).

The Importance of Retrieval Cues

A classic study conducted by Tulving and Pearlstone (1966) illustrates the important role that retrieval cues play in remembering. People were given lists to remember containing words from several meaningful categories (types of animals, birds, vegetables, and so on). Later, people were asked to remember the words either with or without the aid of retrieval cues, which were the category names. Half were asked to recall the words without cues, a condition called **free recall**; the other half were given the category names to help them remember, known as **cued recall**. People in the cued-recall condition recalled nearly twice as many words, presumably because the category names helped them gain access to the previously stored material.

Although these results are not surprising, they have important implications for how we need to think about remembering. Because people performed poorly in the free-recall condition, it's tempting to conclude they never learned the material or simply forgot many of the items from the list. But performance in the cued-recall condition shows that the material wasn't lost—it just couldn't be accessed. With the right retrieval cues—in this case the category names—the "lost" material could be remembered with ease. Memory researchers believe that most, if not all, instances of forgetting are caused by a failure to use the right kinds of retrieval cues. Once information is encoded, it is available somewhere in the brain; you simply need appropriate retrieval cues to gain access.

This is the main reason elaboration is an effective strategy for remembering. When you connect material to existing knowledge, creating a rich and elaborate memory record, you're effectively increasing the number of potential retrieval cues. The more retrieval cues, the more likely you'll be able to access the memory record later on. It's also the main reason mnemonic techniques such as the peg-word method work so well—they establish readily available retrieval cues as part of the learning process (e.g., counting to 10 provides immediate access to the relevant "pegs").

Can you name all of your third-grade classmates? Probably not, but your memory is sure to improve if you're given a class photo to use as a retrieval cue.

iStockPhoto/FatCamera

The Encoding–Retrieval Match

Increasing the number of potential retrieval cues helps, but it also helps if the cue matches the memory that was encoded. If you think about the sound of a word during its original presentation, rather than its appearance, then a cue that rhymes with the stored word will be more effective than a visual cue. Similarly, if you think about the meaning of a word during study, then an effective cue will get you to think about the encoded word's meaning during retrieval. Retrieval cues are effective to the extent that they match the way information was originally encoded.

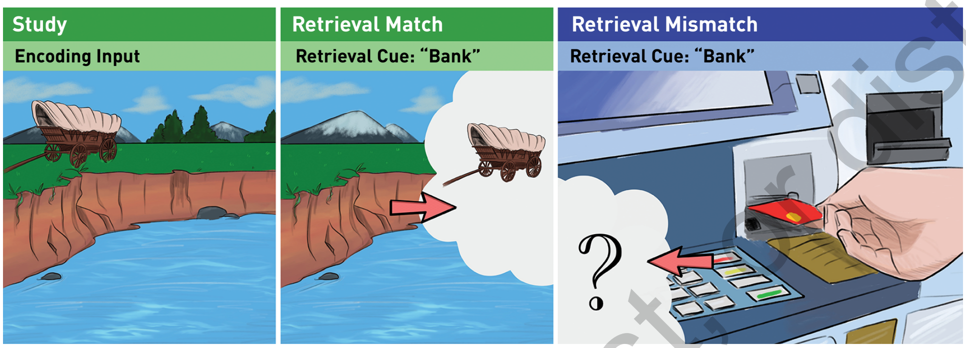
In years to come, these family members may find it easier to remember this welcome-home party at times when they're happy than when they're sad. How does this occurrence reflect the encoding–retrieval match?

Cavan Images / Alamy Stock Photo

Let's consider an example. Suppose you're asked to remember two words: BANK and WAGON. To improve retention, you form a visual image of a WAGON perched on the BANK of a river (see Figure 8.8). Later BANK is provided as a retrieval cue. Will it help you remember WAGON? Probably, but only if you interpret the retrieval cue BANK to mean a slope immediately bordering a river. If for some reason you think about BANK as a place to keep money, you probably won't recover WAGON successfully. A retrieval cue works well only if you interpret it in the proper way. By "proper," psychologists mean that the cue must be interpreted in a way that matches the original encoding. There are some exceptions to this general rule (Nairne, 2002b), but a good encoding–retrieval match is one of the most important factors to consider when seeking a useful retrieval cue.

FIGURE 8.8 ■ The Encoding–Retrieval Match

Memory often depends on how well retrieval cues match the way information was originally studied or encoded. Suppose you're asked to remember the word pair BANK–WAGON. You form a visual image of a wagon teetering on the edge of a riverbank. When presented later with the retrieval cue BANK, you're more likely to remember WAGON if you interpret the cue as something bordering a river than as a place to keep money.



Illustrated by Sarah Yeh

The encoding–retrieval match helps to explain why remembering is often state or context dependent. It turns out that divers can remember important safety information better if they learn the information while diving rather than on land (K. M. Martin & Aggleton, 1993). Presumably, there's a better match between encoding and retrieval when information is learned and tested in the same environment. Another example is childhood, or infantile, amnesia: Most of us have a difficult time remembering things that happened to us before the age of 4 or 5. However, it's likely that we interpreted the world very differently when we were small. Childhood amnesia may result, then, from a poor match between the present and the distant past. We see and interpret events differently now than we did as children, so we have few effective retrieval cues available for remembering childhood events (Jack & Hayne, 2010).

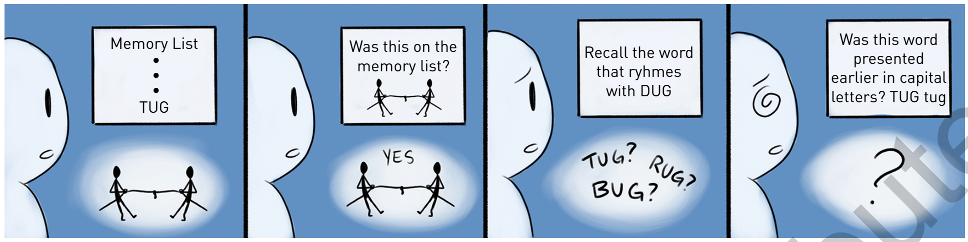
Transfer-Appropriate Processing

Is there any way to guarantee a good encoding–retrieval match? One way is to pay close attention to the conditions likely to be present when you need to remember. You can engage in what psychologists call **transfer-appropriate processing**, which means you should encode material using the same kind of mental processes that'll be required during the test. Matching the mental processes used during study and test increases the chances that effective retrieval cues will be available (Lockhart, 2002).

To illustrate, let's assume you're asked to remember the word TUG for a later memory test (see Figure 8.9). If you form a visual image of a tugboat and you're then specifically asked about a tugboat on the memory test, you'll probably perform well. But suppose you're asked instead to remember whether the word TUG was printed in upper- or lowercase letters. All of the elaboration in the world isn't going to help you unless you've specifically encoded the way the letters were shaped ("TUG," not "tug"). The lesson of transfer-appropriate processing is that you need to consider the nature of the test before you can decide how to study most effectively. For some hints on how to apply the principle of transfer-appropriate processing when you prepare for an exam, see the Practical Solutions feature.

FIGURE 8.9 ■ Transfer-Appropriate Processing

It's useful to study material with the same type of mental processes that you'll be required to use when tested. Suppose you form a visual image of a to-be-remembered word (panel 1). If the test requires you to recognize an image of the word, you should do well (panel 2). But if the test asks how the word sounds (panel 3) or whether the word was presented originally in upper- or lowercase letters (panel 4), you're likely to perform poorly. You need to study in a way that is appropriate to the test.



Illustrated by Sarah Yeh

PRACTICAL SOLUTIONS: STUDYING "APPROPRIATELY" FOR EXAMS

You're now familiar with some techniques for improving memory. You form an elaborate and distinctive memory record during encoding, which helps make certain that relevant retrieval cues are available when you need to remember. Practicing retrieval, through repeated self-testing, is one solid way to guarantee good performance over the long term. It also helps to space your practice—don't cram all of your studying and self-testing into one marathon session the night before the test. By studying the material at different times, and in different situations, you increase the chances that the information will be linked to lots of different retrieval cues. Perhaps most important, you should pay particular attention to the concept of transfer-appropriate processing: Make certain that when you test yourself, you do it in a way that resembles what you'll be required to do on the classroom exam.

On a practical level, this means you need to think about the characteristics of an exam before you sit down to study. An essay exam, for example, is a kind of *cued-recall* test—you're given a cue in the form of a test question, and you're required to recall the most appropriate answer. To study for such a test, it's best to practice cued recall: Make up questions relevant to the material and practice recalling the appropriate answer with only the test question as a cue. For a multiple-choice test, which is a kind of *recognition test*, it's necessary to discriminate a correct answer from a group of incorrect answers (called *distractors*). The best way to study for a multiple-choice test is to practice with multiple-choice questions; either make up your own or use questions from a study guide.

Have you ever thought to yourself, "I'll just read the chapter one more time before I go to bed, and I'll ace the exam tomorrow"? Think about it from the perspective of transfer-appropriate processing—what exactly does the typical exam ask you to do? Exams don't measure the speed or fluency with which the chapter can be *read*. Most exams require you to retrieve the material in the presence of cues. So, it makes a lot of sense to practice retrieving the information rather than simply reading it. Learn the material by reading the chapter but prepare for the exam by using processes similar to those required by the test. Practice reproducing the material by answering questions from memory or practice, discriminating correct from incorrect answers by responding to a variety of multiple-choice questions.

Reconstructive Remembering

Retrieval cues guide remembering in much the same way that a physical message guides the processes of perception. As you may recall from Chapter 5, what you "see" really depends on both the incoming message and the expectations you hold about what's "out there." In a similar way, remembering depends on more than just a retrieval cue—your expectations and beliefs color an act of remembering just as they color what you see and hear. Think about what you had for breakfast two weeks ago. Did you skip breakfast or, perhaps, gulp down a quick bowl of cereal? It turns out that what you "remember" in a case like this often corresponds more to habit than to actual fact. If you regularly eat a bowl of cereal in the morning, then eating cereal is what you're likely to recall, even if you broke the routine on that particular day and had a bagel.

Memory Schemas

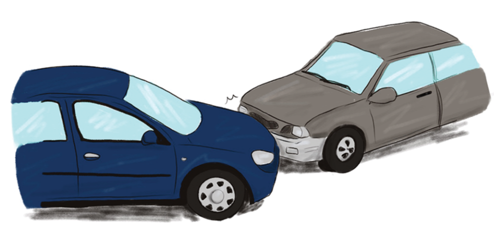
To understand why memory acts in this way, we must return to that vast storehouse of information in the brain—the repository of episodic, procedural, and especially semantic memories. As you know, we store more than facts in long-term memory—we also store relationships among facts. You know, for example, that houses contain rooms with walls, require insurance protection, and are susceptible to burning down. You know that college students like to sleep late, wear jeans, and listen to loud music. These large clusters of related facts are organized into knowledge structures called **schemas**. Schemas can be about people, places, or activities—we even have them for routines such as going to a restaurant, visiting the local urgent care center, or following daily eating habits. When you remember, you use these organized knowledge packages to help recover the past. So when someone asks you what you ate for breakfast two weeks ago, you can confidently answer "cereal" because you know cereal is what you usually eat for breakfast. You don't have to remember the specific episode; you can rely on your general knowledge.

The trouble with schema-based remembering is that it can easily lead to false or inaccurate retention. You might remember something that's completely wrong—it didn't really happen—yet still be convinced your memory is accurate. (Remember our earlier discussion of flashbulb memories?) Nearly 90 years ago, an English psychologist named Frederic Bartlett asked undergraduates to read an unfamiliar Native North American folktale about people who traveled up a river to battle with some warrior "ghosts" (the story's title was "The War of the Ghosts"). In recalling the story sometime later, the students tended to distort facts, omit details, and fill in information that was not included in the original version. For example, familiar things were substituted for unfamiliar things—the word *boat* was substituted for *canoe*; "hunting seals" was replaced with "hunting beavers." Because these things were not in the story, Bartlett assumed his participants must have used their prior knowledge to reconstruct what they remembered—even though they were convinced they were remembering the material accurately (Bartlett, 1932).

A similar point was made more recently by Loftus and Palmer (1974). Undergraduates were shown a short film depicting an automobile accident. Later, when questioned about the film, the students were asked to estimate how fast the cars were traveling just prior to the accident. Some students were asked to estimate the speed of the cars just before they *smashed* into each other; others were asked how fast the

FIGURE 8.10 ■ Schema-Based Remembering

Loftus and Palmer (1974) found that students remembered cars traveling faster when retrieval instructions used the word *smashed* instead of *contacted*. All people saw the same film, but their different schemas for the words *smashed* and *contacted* presumably caused them to reconstruct their memories differently.

Recall Instructions	Schema	Response
"How fast were the cars going when they smashed into each other?"		"About 42 mph."
"How fast were the cars going when they contacted into each other?"		"About 32 mph."

Illustrated by Sarah Yeh

cars were going before they *contacted* each other. Notice the difference between the words—the schema for *smashed* implies that the cars were traveling at a high rate of speed, whereas *contacted* suggests that the cars were moving slowly. As shown in Figure 8.10, people who heard the word *smashed* in the question estimated that the cars were traveling about 42 miles per hour; people in the *contacted* group gave an estimate of about 10 miles per hour slower.

Once again, these results show that memory is importantly influenced by general knowledge, as well as by expectations. Everyone in the Loftus and Palmer experiment saw the same film, but what people remembered depended on how the questions were worded—that is, on whether people were led to believe that the cars were going fast or slow. In addition to giving estimates of speed, some were asked whether any broken glass was present in the accident scene. When *smashed* was used in the speed question, people were much more likely to incorrectly remember seeing broken glass, even though there wasn't any in the original film. By asking the right kinds of questions during testing, it's possible to make people think they experienced things that did not occur. As Loftus (2018) has emphasized, these findings suggest that caution must be exercised in interpreting the testimony of any eyewitness—reconstructive factors can always be involved.

Here's an easy way to demonstrate schema-based remembering for yourself: Read the following list of words aloud to a group of friends:

BED REST AWAKE TIRED DREAM WAKE SNOOZE
BLANKET DOZE SLUMBER SNORE NAP YAWN DROWSY

Now ask your friends to write down all the words they've just heard. The chances are very good that someone will remember an item that was not on the list, especially the word SLEEP. In experiments using lists of such related items, people have been found to recall nonpresented items (e.g., SLEEP) nearly 50% of the time (Deese, 1959; Roediger & McDermott, 1995). The chances of false memory increase even more when recognition memory is tested—that is, when you're given the word SLEEP and asked if it was presented on the list (K. B. McDermott & Roediger, 1998). What's behind this effect? Obviously, the word SLEEP is highly related to the words on the list. It seems likely that people recognize the relationships among the words and use this knowledge to help them remember. This is a very effective strategy for remembering, but it can lead to false recollections.

Despite the mistakes, schema-based remembering clearly has adaptive value. By relying on preexisting knowledge to "fill in the gaps" or to help interpret fuzzy recollections, you increase the chances that your responses in new environments will be appropriate—after all, the past is usually the best predictor of the future. You can also use your schematic knowledge to "correct" for any minor details you may have missed during the original exposure. If you already have a pretty good idea of what goes on during a visit to a fast-food restaurant, your mind doesn't need to expend a great deal of effort attending to details the next time you enter a McDonald's. You can rely on your prior knowledge to capture the gist of the experience, even though, on the downside, you may recollect a few things that didn't actually happen.

The point made earlier about eyewitness testimony is important, however. Some people, including the members of juries, don't understand the reconstructive nature of remembering. There is evidence that the general public believes that memories are highly accurate, especially when someone expresses lots of confidence about the memory. For example, in one recent survey, nearly 40% of the public agreed with the following statement: "In my opinion, the testimony of one confident eyewitness should be enough to convict a defendant of a crime." When expert memory researchers were asked the same question, none agreed with the statement (Simons & Chabris, 2011). This certainly suggests that too much weight may be given by juries to eyewitness testimony. Eyewitness testimony can be accurate, but recognizing the reconstructive nature of memory should make one skeptical about any remembered event, regardless of its importance or even the confidence of the rememberer (for an important exception, though, see Wixted & Wells, 2017). A recent study suggests that public beliefs about memory may be getting somewhat more accurate, but many individuals still hold inaccurate beliefs about how memory functions (Brewin et al., 2019).

Remembering Without Awareness

Up to this point, we've concentrated on conscious, willful acts of remembering—that is, situations in which you're consciously intending to remember something (such as what you ate for breakfast or the words from a memory list). But we often remember things without conscious intent or awareness. You speak, walk to work, recognize someone you know—all these things require memory, but you're usually not explicitly trying to remember anything. Psychologists use the term **implicit memory** to describe this kind of remembering. **Explicit memory** is the name researchers use to describe conscious, willful remembering. It turns out that implicit memory—remembering without awareness—follows many of the same rules as explicit memory. For example, both implicit and explicit memory are strongly influenced by retrieval cues. If you look at Figure 8.11, you'll see some examples of word and picture fragments. Your ability to complete one of these fragments improves if you've seen the solution word recently during reading (for example, the word fragment C___L is easier to solve if the word CAMEL has been encountered in the prior 24 hours). But importantly, you don't need to remember seeing the word. Your performance improves even if you don't consciously remember the word (which makes the remembering implicit). At the same time, performance depends importantly on whether the earlier encounter matches the fragment. If you need to solve a picture fragment, then you're helped more if the earlier encounter was in the form of a picture—such as seeing a picture of a camel—rather than a word (K. B. McDermott & Roediger, 1994). Once again, the conditions during testing need to match the conditions present during the original exposure.

FIGURE 8.11 ■ Implicit Memory Tests

The person's task in each test is to complete the picture or word fragment so as to identify the object shown on the far right.

Picture fragment completion				
Word fragment completion	C _ _ _ L	CA _ _ L	C _ M _ L	CAMEL

Source: From Snodgrass, J. G., & Feenan, K. (1990). Copyright © 1990, American Psychological Association. Reprinted with permission.

There are situations in which implicit memory appears to act somewhat differently than explicit memory. One of the most interesting cases is with amnesia, memory loss caused by a physical problem. It turns out that people who suffer from severe amnesia—for example, they show little memory for a sentence spoken moments before—often show little decline in implicit memory. We'll discuss this topic in more detail later in the chapter. There's also evidence suggesting that older adults have better implicit memory for irrelevant information (things that are not central to the task at hand) than younger adults (Gopie et al., 2011). In addition, encoding strategies that typically improve conscious, willful remembering often have little or no effect on implicit memory (Roediger et al., 1992). If you think about the meaning of the material, which induces elaboration, you're much more likely to recall it on an explicit test of memory, such as recall or recognition. But the same improvement often isn't found when memory is tested using an implicit test, such as solving word fragment problems (Graf et al., 1982). Differences such as these have led some researchers to suggest that explicit and implicit memories are controlled by different processing systems in the brain (Squire & Dede, 2015). Many research studies have suggested that explicit memory relies primarily on the medial temporal lobes that include the hippocampus (first described in Chapter 3). Implicit memory, however, relies less on these areas and more on the neocortex and striatum. These differences in brain area specialization across types of memory are seen clearly in patients with damage to the medial temporal lobes; these patients have great difficulty performing explicit tasks but perform more normally on implicit tasks. We will consider these differences further in the section on the neuroscience of forgetting later in this chapter.

KNOWLEDGE CHECK 8.3

Now test your knowledge about how we use cues to help us remember by answering the following questions. Fill in the blanks with one of the following terms: *cued recall, explicit memory, free recall, implicit memory, schema, transfer-appropriate processing.* (You will find the answers in the Appendix.)

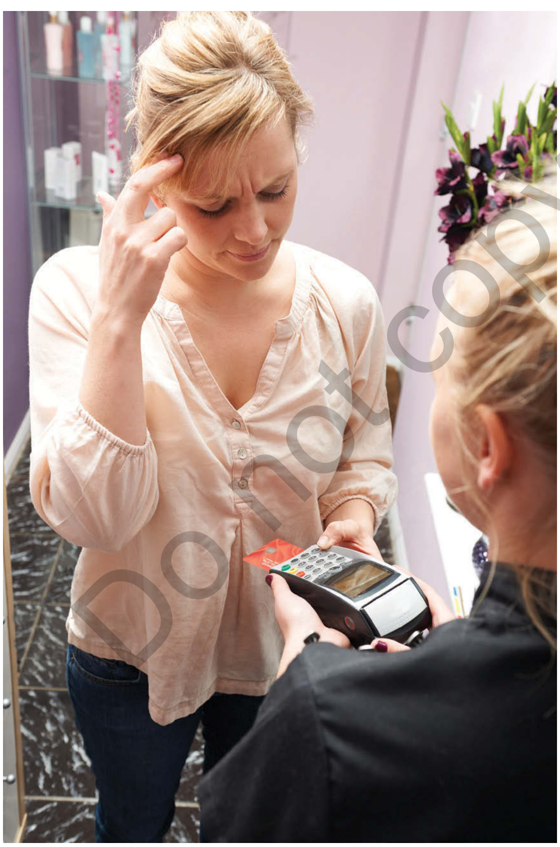
1. An organized knowledge package that's stored in long-term memory: ______
2. Remembering without awareness: ______
3. Studying for a multiple-choice test by writing your own multiple-choice questions: ______
4. Remembering material without the aid of any external retrieval cues: ______

UPDATING MEMORY

Like other storage devices, the mind is susceptible to clutter. Effective remembering often hinges on your ability to successfully discriminate one occurrence from another—you need to remember where you parked your car today, not yesterday, or your current address, not a previous one. What if you felt the urge to buy two dozen paper cups every time you entered the grocery store because one time last year you needed paper cups for a party? **Forgetting**, the loss of accessibility to previously stored material, is one of the most important and adaptive properties of your memory system (Bjork, 1989; Nairne & Pandeirada, 2008).

If you need further convincing, consider the case of a Russian journalist known as S. who possessed an extraordinary ability to remember. Through a fluke of nature, S. reacted automatically to stimuli in ways that formed unusual and distinctive encodings. When he heard a tone pitched at 500 hertz, S. reported seeing "a dense orange color which made him feel as though a needle had been thrust into his spine" (Luria, 1968, p. 24). For a 3,000-hertz tone, S. claimed that it "looks something like a firework tinged with a pink-red hue. The strip of color feels rough and unpleasant, and it has an ugly taste—rather like that of a briny pickle" (Luria, 1968, p. 24).

S. had a remarkable memory—he could remember grids of numbers perfectly after 15 years—but he suffered a near fatal flaw: He simply couldn't forget. He had trouble reading books because words or phrases so flooded his mind with previous associations that he had great difficulty concentrating. He would notice, for example, small errors in the text: If a character entered the story wearing a cap and in later pages was described without a cap, S. would become greatly disturbed and disappointed in the author. He had trouble holding a job or even a sustained conversation. For S., the failure to forget produced a truly cluttered mind.



Forgetting is often bothersome, but it can have considerable adaptive value.

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Types of Forgetting

When you think of people with poor memory abilities, you may think of older individuals who have some memory deficits, or individuals who have suffered some form of brain damage. But even those with normal memory abilities can suffer from unwanted forgetting. In his book *The Seven Sins of Memory*, Daniel Schacter (2001) described seven common memory failures that occur in individuals with normal memory abilities (see Concept Review 8.2). He describes these "sins" of memory as by-products of the way our memories function and as typical of us all to varying degrees. The "sins" Schacter describes are transience, absentmindedness, blocking, source misattribution, suggestibility, bias, and persistence. Let's consider what each of these failures are.

Transience is a term for normal forgetting of information over time. Later in this section, we'll discuss some possible causes of normal forgetting and the form this forgetting takes. A lack of attention during encoding or retrieval can result in poor memory. Schacter calls this memory failure *absentmindedness*. A good example of this memory failure is not remembering where you have placed something you need to find, such as your car keys. If you do not pay attention to their location when you put them down, there is a good chance you'll not remember where they are (unless you always put them in the same place). This is also one of the main reasons why it's tough to remember the name of someone you've just met—you're too distracted to encode the person's name fully when you first hear it. Schacter describes *blocking* as an experience of knowing that you know information but being unable to retrieve it. When we learn something from one source but remember it as having occurred from another, we suffer *source misattribution*. For example, there are likely times when you have a thought or idea about something that you think is an original thought you generated, but in reality, you read or heard about the idea somewhere else first.

Suggestibility occurs when others' suggestions and statements alter our memories for events in ways we do not even realize. Suggestibility can alter actual memories and even create false memories for events we have never experienced. *Bias* is a similar memory failure to suggestibility. Bias occurs when our current experiences or knowledge alter our memory of a past experience. For example, after going through an unpleasant breakup with a romantic partner, you may remember a happy event you experienced with that partner as more negative than it actually was. Finally, *persistence* is a memory "sin" in which we experience unwanted memories over and over.

In many cases, memory functioning seems so effortless to us that we do not notice these memory failures at all. However, when these errors or failures arise (e.g., not remembering an important concept during an exam), we realize the limitations of our memory abilities. Next, we'll consider the form forgetting takes over time.

CONCEPT REVIEW 8.2

THE SEVEN "SINS" OF MEMORY FROM SCHACTER (2001)

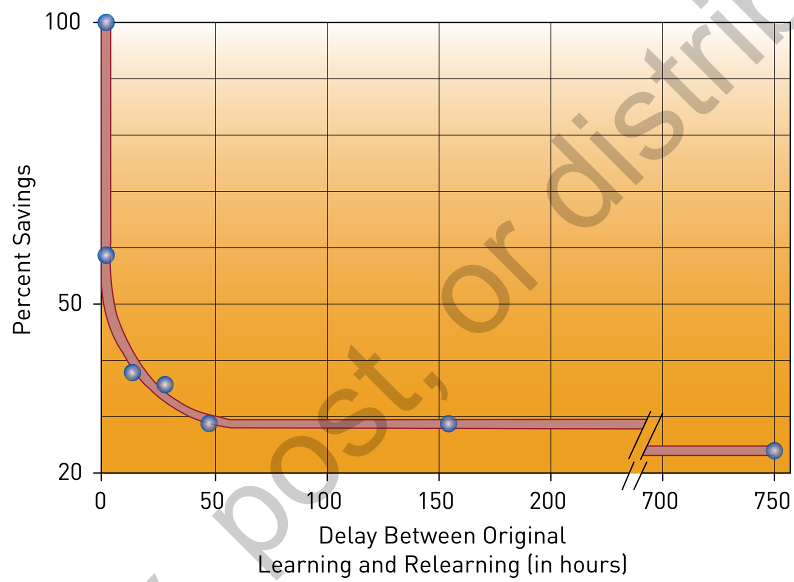
Sin	Description	Example
Transience	Typical forgetting over time	As Diana got to the end of the week, she forgot what she had for breakfast on Monday.
Absentmindedness	Lack of attention at encoding/retrieval, which reduces memory	Jeff is constantly losing his keys because he doesn't pay attention to where he puts them down.
Blocking	Inability to retrieve information you know that you know	Ebony can't remember the name of the actor in the movie she saw last night; she can only think of a name she knows is wrong.
Source misattribution	Misremembering where you learned something	Harry is sure he heard about a new type of drink from his friend, but he actually saw it on social media.
Suggestibility	Alteration of memory from an outside source	Tarif witnessed a blue car crash into a stop sign, but after hearing other witnesses' reports, he later remembers the car crashing into a utility pole.
Bias	Alteration of memory due to later experiences	Lola remembers a pleasant first date with her new boyfriend after several good dates with him, but in reality, the first date didn't go that well.
Persistence	Unwanted memories coming to mind	After having his phone stolen in a mugging, Steve can't stop reliving the event.

How Quickly Do We Forget?

For most people, once an item has left the immediate present, it's forgotten in a regular and systematic way. How quickly an item is forgotten depends on several factors: how the item was initially encoded, whether it was encountered again at some later time, and the kinds of retrieval cues present at the point of remembering. But in general, the course of forgetting looks like the curve shown in Figure 8.12. Most of the forgetting occurs early, but you will continue to forget gradually for a long period following the initial exposure (Murre & Dros, 2015).

FIGURE 8.12 ■ The Ebbinghaus Forgetting Curve

German philosopher Hermann Ebbinghaus memorized lists of nonsense syllables and then measured how long it took to relearn the same material after various delays. Fifty percent savings means it took half as long to relearn the list as it did to learn it originally; 0% savings would mean that it took as long to relearn the list as it did to learn the list originally.



Hermann Ebbinghaus (1850–1909)

Pictorial Press Ltd / Alamy Stock Photo

The forgetting curve shown in Figure 8.12 is taken from some classic work by German philosopher Hermann Ebbinghaus (1885/1964), one of the first researchers to investigate memory and forgetting scientifically. Isolated in his study, he forced himself to learn lists of nonsense syllables (such as ZOK) and then measured how long it took to relearn the same material after various delays (a technique called the *savings method*). As the figure shows, the longer the delay after original learning, the greater effort Ebbinghaus had to spend relearning the list. The Ebbinghaus forgetting function—a rapid loss followed by a more gradual decline—is typical of forgetting. Similar forgetting functions are found for a variety of materials, even for complex skills such as flying an airplane (Fleishman & Parker, 1962) or performing cardiopulmonary resuscitation (McKenna & Glendon, 1985).

Even memories for everyday things, such as the names of high school classmates or material learned in school, are forgotten in regular and systematic ways. In one study, Bahrick (1984) studied memory for a foreign language (Spanish) over intervals that ranged from about 1 to 50 years. In another study, Bahrick and Hall (1991) examined the retention of high school mathematics over 50 years. In both cases, there was rapid loss of recently learned material, followed by more gradual loss, but a considerable amount of knowledge was retained indefinitely. What's surprising about these studies is that a fair amount of the knowledge remained, even though the participants claimed to have not rehearsed or thought about the material in over half a century. (Maybe there's hope for education yet!)

There's one more characteristic of long-term forgetting that you'll probably find interesting. When older adults are asked to recall and date events from their past, not surprisingly they tend to remember things from the more recent past best. However, there's a "bump" in the forgetting curve for events that happened between late adolescence and about age 30 (Koppel & Berntsen, 2014). For some reason, we retain events from this period particularly well—or, at least, these are the events that we're apt to recall in our older years. This is known as the "reminiscence bump," and psychologists aren't exactly certain why it happens. We experience lots of "firsts" during this period (career, possibly marriage and family), so perhaps we simply repeatedly rehearse what happens during the 20-something period throughout our lives (Rubin & Berntsen, 2003). It's also possible that we learn from our culture that important things happen during the "bump" period, so we tend to search for memories from that period when we recall our past (Bohn & Berntsen, 2011).

In addition, research suggests that the way memory is cued for events can affect the age at which memories are reported. Odor cues (i.e., specific scents) trigger earlier memories than word cues, whereas asking people to report important autobiographical memories produces the classic reminiscence bump with most memories reported from people's early 20s. These results suggest that retrieval plays an important role in the reminiscence bump along with encoding (Koppel & Rubin, 2016).

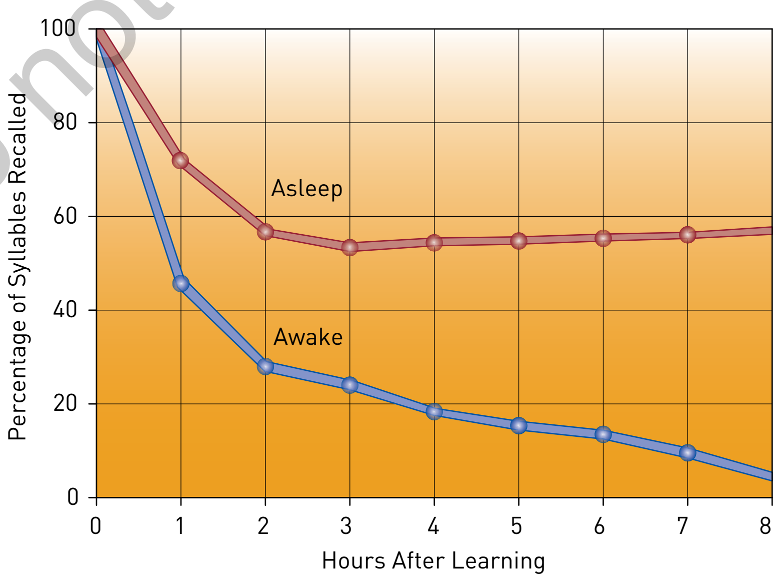
Why Do We Forget?

We can agree that it's adaptive to forget, and we can measure how quickly information becomes unavailable over time, but what causes forgetting? As we discussed earlier, most memory researchers believe that forgetting is cue dependent—you fail to remember a prior event because you don't have the right retrieval cues. But it's also possible that memories simply fade with the passage of time in accordance with a "law of use" (Thorndike, 1914). If you fail to practice a learned habit, such as playing the piano, the habit fades, or *decays*, spontaneously with time.

However, **decay**—the idea that memories fade due to the passage of time—cannot explain most instances of forgetting. For one thing, as you've seen, memories that appear to have been forgotten can be remembered later under the right retrieval conditions. In addition, people often remember trivial things (such as a joke) for years but forget important things that once received a great deal of practice (such as elementary geometry). Even more significant, just because memories are lost with time doesn't mean that *time* alone is the cause. A nail left outside becomes rusty with time, but it is not the passage of time that creates the rust—processes other than time (oxidation, in the case of the rusty nail) produce the changes.

FIGURE 8.13 ■ Interference and Memory

The activities that occur after learning affect how well stored information is remembered. In this study by J. G. Jenkins and Dallenbach (1924), the students remembered better if they slept during the retention interval than if they remained awake. Presumably, the waking activities caused interference.



Mechanisms of Forgetting: Retroactive Interference

In forgetting, the "other processes"—which are correlated with the passage of time but are not created by time—often depend on the establishment of other memories. We constantly learn new things, and these new memories compete, or interfere, with the recovery of old memories. College students tend to move around a lot, so every time you get a new apartment you need to learn a new home address. Once you've got the new address memorized, it becomes more difficult to retrieve your old address, even if you actively try to remember. The retrieval cue "home address" has now become associated with something new; as a result, it loses its capacity to produce the old information. Psychologists use the term **retroactive interference** to refer to cases where the formation of new memories hurts the retention of old memories.

In a classic study of retroactive interference, J. G. Jenkins and Dallenbach (1924) asked two students from Cornell University to live in a laboratory for several weeks and learn lists of nonsense syllables either just before bed or early in the morning. The students were tested 1, 2, 4, or 8 hours after learning. The results, which are shown in Figure 8.13, were clear: When the students slept during the delay interval, they remembered more than when they remained awake. A constant amount of time passed in both conditions, so a decay theory would predict no differences between the conditions. The findings suggest it was the activities that occurred during the students' waking hours that produced the information loss. When awake, the students formed new memories, which interfered with recovery of the old material.

Mechanisms of Forgetting: Proactive Interference

It's not just the learning of new information that produces forgetting. Previously learned information can also produce interference. **Proactive interference** occurs when old memories interfere with the recovery of new memories. Suppose English is your native language but you move to Portugal on business. You learn the Portuguese language, fluently, but you find it difficult to stop English words or phrases from coming to mind when you speak. You know the Portuguese word for train is *comboio*, but you find it hard to suppress saying "train" when you're talking in Portuguese (at least for a while). That's proactive interference—old memories interfere with the recovery of new memories. Prior knowledge and habits interfere with the retention of new material.

Most memory researchers believe that forgetting is usually caused by interference, although it's conceivable that decay might operate in certain situations. One possibility is that decay operates when we remember over the very short term—that is, in sensory memory and short-term memory (Barrouillet et al., 2012; see also Ricker et al., 2020). It's also possible that when we learn new material, older memories are "overwritten" and permanently lost (Loftus & Loftus, 1980). But generally, we don't *lose* material with time; the material simply becomes harder to remember because other things interfere with the retrieval process. As new memories are encoded, old retrieval cues become less effective because those cues are now associated with new things.

Motivated or Purposeful Forgetting

Highly unusual or emotional events lead to distinctive, and therefore easy-to-remember, memory records. The adaptive value of a system that "stamps in" significant events is easy to understand—remembering such events can increase our ability to survive. But what about those cases in which it's adaptive to *forget* something, such as a traumatic instance of child abuse or the witnessing of a violent crime?

The idea that the mind might actively repress, or inhibit, certain memory records is an important ingredient of Sigmund Freud's psychoanalytic theory, as you'll see when we discuss personality theories in Chapter 11. Freud introduced **repression** as a "defense mechanism" to push threatening thoughts, memories, and feelings out of conscious awareness. According to Freud, these repressed memories retain the capacity to affect behavior at an unconscious level but cannot be remembered in the conventional sense. The result is a reduction in the experience of anxiety.

The Evidence for Repression

Modern researchers remain undecided about the scientific validity of repression. People typically recall more pleasant than unpleasant events (Wagenaar, 1986), and painful experiences, such as the pain associated with childbirth, also seem to be recollected less well with the passage of time (Robinson et al., 1980). There are also many cases, reported mainly in clinical settings, of what appear to be the repression of traumatic experiences.

People are more likely to recall pleasant than unpleasant experiences, perhaps because they're reluctant to rehearse unpleasant experiences.

Katelyn Mulcahy/Stringer/Getty Images

For example, in one study, 475 adults undergoing psychotherapy were asked about memories of childhood sexual abuse. Each had reported an incident of abuse during childhood, and each was asked the following specific question: "During the period of time between when the first forced sexual encounter happened and your 18th birthday, was there ever a time when you could not remember the forced sexual experience?" (Briere & Conte, 1993). Fifty-nine percent of the people who answered the question responded "Yes," suggesting that the memories had been pushed out of consciousness for at least some period of time. In another study supporting the same conclusion, L. M. Williams (1992) asked 100 women who had been medically treated for sexual abuse as children—the abuse was documented by hospital and other records—whether they remembered the incident 17 years later. Thirty-eight percent of those responding reported no memory of the abuse, again providing support for the concept of repression.

But does this really mean that the forgetting was caused by repression? It's possible that people tend to remember positive events because these are the types of events that we rehearse and relate to others. The fact that painful experiences are forgotten with the passage of time can be explained in lots of ways—many things are forgotten with the passage of time, especially those unlikely to be rehearsed. In fact, victims of childhood sexual abuse often tell researchers that they deliberately try to avoid thinking about the abuse (McNally & Geraerts, 2009). It's also difficult for researchers to understand why some traumatic memories, such as those typically seen in posttraumatic stress disorder (PTSD), remain extremely difficult to suppress or forget.

There have been attempts to simulate repression in the laboratory. No, people are not exposed to traumatic events; instead, they're simply asked to actively prevent previously learned material from coming to mind. For example, if you've been taught to recall SOCKS every time you're given the word JOY, I might ask you to actively repress thinking about SOCKS the next time you see JOY. Under these conditions, there's some evidence that SOCKS then becomes harder to recall—you've suppressed its representation in memory (M. C. Anderson & Green, 2001; but see Bulevich et al., 2006). Recent evidence suggests as well that it is easier to suppress emotionally negative material than positive material (A. J. Lambert et al., 2010). Moreover, people with severe forms of PTSD may be less able to control these suppression mechanisms (Catarino et al., 2015). But whether the kinds of suppression effects observed in the laboratory are the same as those seen in clinical settings remains a matter of dispute (Erdelyi, 2010). Concept Review 8.3 reviews the different causes of forgetting discussed in this section.

CONCEPT REVIEW 8.3
MECHANISMS OF FORGETTING

Mechanism	Description	Example
Cue dependence	One fails to remember an event due to a lack of appropriate cues.	Although Susan would recognize a definition of semantic memory on a multiple-choice test, she can't think of it for a fill-in-the-blank test.
Decay	Memories fade with the passage of time.	After only a month of lessons, and then 6 years of not playing the piano, Shao forgets how to play.
Proactive interference	Old memories interfere with the recovery of new memories.	Bruce is so impressed with the first person he met at the party that he can't remember the names of those he met later.
Retroactive interference	New memories interfere with the recovery of old memories.	Filling out a job application, Seth can remember only his most recent address, not the one before it.
Motivated forgetting	Traumatic experiences are forgotten to reduce anxiety.	Jackie can't remember too much about the day her parents were seriously injured in an accident.

Whether these laboratory studies really tell us anything about the forgetting of traumatic events remains uncertain. However, as Freud noted, a process of repression might be adaptive in the sense that it can prevent or reduce anxiety. It may also be the case that forgotten events continue to exert indirect influences on behavior in ways that bypass awareness. But the data do suggest that memories, whether "recovered" in therapy or simply in the normal course of everyday activities, should not be taken at face value. It is useful for people to use prior knowledge, as well as current expectations, to help them remember—but perhaps at the cost of sometimes remembering things that didn't actually happen.

The Neuroscience of Forgetting

Forgetting can also be caused by physical problems in the brain, such as those induced by injury or illness. Psychologists use the term **amnesia** to refer to forgetting caused by some kind of physical problem. (Another type of amnesia that's psychological in origin arises from something called a dissociative disorder, but we'll delay our discussion of this kind of forgetting until Chapter 14.)

Types of Amnesia

There are two major kinds of amnesia, retrograde and anterograde. **Retrograde amnesia** is memory loss for events that happened prior to the point of injury (you can think of *retro* as meaning "backward in time"). People who are in automobile accidents, or who receive a sharp blow to the head, often have trouble remembering the events leading directly up to the accident. The memory loss can apply to events that happened only moments before the accident, or the loss can be quite severe; in some cases, patients lose their ability to recall personal experiences that occurred years before the accident. In many cases, fortunately, these memory losses are not permanent and recover slowly over time (Cermak, 1982).

Anterograde amnesia is memory loss for events that happen *after* the point of physical damage. People who suffer from anterograde amnesia often seem locked in the past—they're incapable of forming memories for new experiences. The disorder develops as a result of brain damage, which can occur from the persistent use of alcohol (a condition called *Korsakoff syndrome*), from brain infections (such as viral encephalitis), or, in some cases, as a by-product of brain surgery. One of the most thoroughly studied amnesic patients, known to researchers as H. M., developed the disorder after surgery was performed to remove large portions of his temporal lobes. The purpose of the operation was to reduce the severity of H. M.'s epileptic seizures; the surgery was successful—his seizures were dramatically reduced—but anterograde amnesia developed as an unexpected side effect.

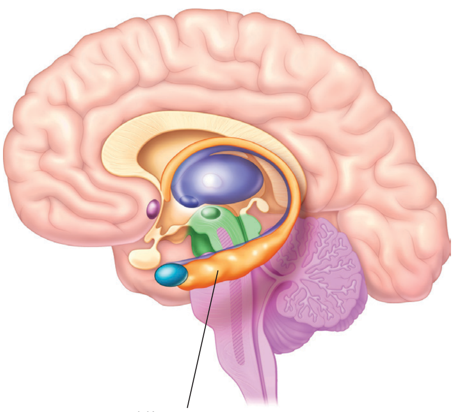
Over the years, patients such as H. M. have been studied in great detail to determine exactly what kinds of memory processing are lost (Milner, 1966). It was originally believed that such patients fail to acquire new memories because some basic encoding mechanisms have been destroyed. It is now clear, however, that these patients can learn a great deal but must be tested in particular ways. If a patient like H. M. is tested implicitly, on a task that does not require *conscious* remembering, performance can approach or even match normal levels. In other words, people with anterograde amnesia perform poorly on explicit memory tasks but perform well on implicit memory tasks.

In one study showing this result, Jacoby and Witherspoon (1982) asked Korsakoff patients with anterograde amnesia to learn homophones for a later memory test. Homophones are words that sound alike but have different meanings and spellings, such as READ and REED. To "bias" a particular interpretation for a given homophone, it was presented as part of a word pair, such as BOOK–READ or, in another condition, SAXOPHONE–REED. (Because the words were presented aloud, the only way to distinguish between the homophones READ and REED was through the accompanying context word BOOK or SAXOPHONE.) Later, the amnesics were asked to recognize the words but were unable to do so—they seemed to have acquired none of the presented information. In a second test, however, the homophones were simply read aloud by the experimenter, and the patients' task was to spell the word. Surprisingly, if the amnesics had earlier received the pair BOOK–READ, they spelled the test homophone READ, but if the homophone had been paired with SAXOPHONE, they spelled it REED.

These results suggest that the homophones were learned by the amnesic patients. The way the patients spelled the homophone during the test depended on their prior experience. Other experiments have revealed similar findings. For example, amnesics are more likely to complete a word fragment (such as E_E__AN_) correctly if they've seen the word before, but if they're asked to recall the word, their performance falters (Graf & Schacter, 1985). Patients who suffer from anterograde amnesia fail to retrieve past experiences whenever they must *consciously* recollect the experience; when the past is assessed indirectly, through a task that does not require conscious remembering, these amnesics often perform at normal levels.

FIGURE 8.14 ■ The Hippocampus

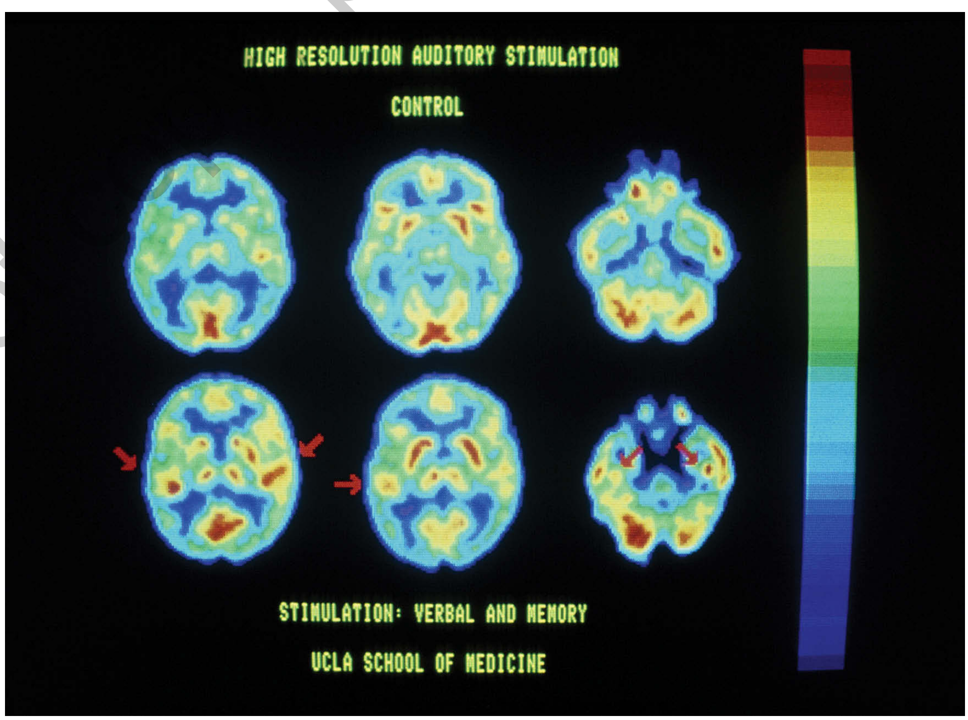
The hippocampus (seen at the location marked in this image of the right hemisphere of the brain) is an important brain structure for intentional retrieval of memories.



Where Are Memories Stored?

The study of individuals with brain damage, such as Korsakoff patients, has also encouraged researchers to draw tentative conclusions about how and where memories are stored in the brain. We touched on this issue in Chapter 3 when we considered biological processes. In that chapter, special attention was paid to a structure called the *hippocampus*, which most brain researchers believe is critically involved in the formation and storage of memories (e.g., Voss et al., 2017). Damage to the hippocampus, as well as to surrounding structures in the medial temporal brain area, leads to memory problems in a wide variety of species, including humans, monkeys, and rats. Areas surrounding the hippocampus also "light up" (i.e., become more active) in neuroimaging studies when people are asked to recall specific material; in fact, some researchers have suggested that it's even possible to detect specific memories in people by examining the patterns of neural activation around the hippocampus, seen in Figure 8.14 (Chadwick et al., 2010). However, as described earlier in this chapter, damage to the hippocampus affects memory when it is tested explicitly, but not implicitly, suggesting that different brain areas are involved based on how retrieval of the memory occurs.

Thus, no single brain structure, or group of structures, is responsible for all instances of remembering and forgetting. Things are vastly interconnected in the brain, and activity in one part of the brain usually depends on activity in other parts. The regions of the brain involved in the storage of memories also depend



This PET scan shows regions of brain activity during auditory stimulation. The arrows point to areas inside the temporal lobes that become active when words are heard; these same areas are thought to be associated with some kinds of memory.

Dr. John Mazziotta et al. / Science Source on the type of processing involved. For example, when you try to remember something, the regions of the brain activated during original learning are activated again. So, if you formed a visual image of an object when you first studied it, the visual areas of your brain will be reactivated when you retrieve it (C. E. Webb et al., 2016). If your original encoding was tinged with emotion, the areas of the brain involved in emotional processing will be activated when you remember the event (Danker & Anderson, 2010).

Certain kinds of memory loss, such as those found in Alzheimer's disease, have been linked to inadequate supplies of neurotransmitters in the brain (Francis et al., 2010). But damage to a part of the brain tied to the production of a neurotransmitter (such as acetylcholine) probably has consequences for all regions of the brain that depend on that neurotransmitter. This makes it difficult to pinpoint where a memory is stored or even where the processing relevant to the storage of memories takes place. Modern technological advances are providing researchers with precise information about activity in the brain, but much remains to be learned about the physical basis of remembering.

KNOWLEDGE CHECK 8.4

Now test your knowledge about forgetting and the updating of memory by deciding whether each of the following statements is true or false. (You will find the answers in the Appendix.)

1. Forgetting is usually slow at first and becomes more rapid as time passes. *True or False*?
2. Most psychologists agree that interference rather than decay is primarily responsible for long-term forgetting. *True or False*?
3. Proactive interference occurs when what you learn at time 2 interferes with what you learned previously at time 1. *True or False*?
4. Anterograde amnesia blocks the learning of new information. *True or False*?
5. People recall more pleasant than unpleasant events over time. *True or False*?
6. Psychologists believe that the hippocampus is involved in some, but not all, instances of remembering. *True or False*?

THE PROBLEMS SOLVED: WHAT MEMORY IS FOR

Time flows continuously, so experiences quickly leave the present and recede backward into the past. To understand the capacity to preserve and recover this past, we considered some of the important problems that our memory systems help us solve.

Remembering Over the Short Term

To improve perception and aid comprehension, internal processes help us remember over the short term. In the case of sensory memory, we retain a relatively pure snapshot of the world, or replica of the environmental message. Sensory memories accurately represent the world as recorded by the senses, but they tend to be short-lived, lasting on the order of a second or less. Short-term memory, in contrast, is the system used to store, think about, and reason with the message once it has undergone perceptual analysis. Items are typically maintained in short-term memory in the form of an "inner voice," and they're forgotten rapidly in the absence of rehearsal. The capacity, or size, of short-term memory is determined by a trade-off between the factors that lead to forgetting over the short term (either decay or interference) and the time-limited process of rehearsal.

Storing Information for the Long Term

To store information over the long term, you need to produce elaborate and distinctive memory records. Focusing on the meaning of the input, relating to-be-remembered information to other things in memory, and forming visual images of the input all lead to distinctive memory records. Forming a visual image is particularly effective, and many memory aids, or mnemonic devices, are based on the use of imagery. Long-term memory also depends on how information is actually presented: Items presented near the beginning and end of a sequence are remembered well, as are items that have been repeated. Spaced or distributed practice turns out to be more effective than massed practice. Finally, practicing retrieval through self-testing is particularly effective in producing long-term retention.

Recovering Information From Cues

Successful remembering depends critically on having the right kinds of retrieval cues. Most forms of forgetting are cue dependent, which means that stored information is not really "lost"; it simply can't be accessed without the appropriate retrieval cues. Effective retrieval cues are generally those that match the conditions present during original learning. It's also the case that when people recover information from cues, they rely on their general knowledge. The past is often reconstructed, and the reconstruction process leads to adaptive, but sometimes inaccurate, recollections of the past.

Updating Memory

Forgetting is a useful process. If we didn't constantly change and update our knowledge about the world, our minds would be cluttered with useless facts, such as where the car was parked last Wednesday. Although the mechanisms of forgetting are still being investigated, it seems unlikely that long-term memories fade as a simple by-product of time. Rather, as we learn new things, previously learned material becomes harder to access. New memories compete and interfere with recovery of the old. With the right kinds of cues, however—cues that discriminate one kind of occurrence from another—previously forgotten material becomes refreshed and available for use once again.

THINKING ABOUT RESEARCH

A summary of a research study in psychology is given in this section. As you read the summary, think about the following questions:

1. Does this study examine encoding processes or retrieval processes? Explain your answer.
2. Which of the seven "sins" of memory do you think is responsible for the results of this study? Why?
3. What kind of memory, implicit or explicit, is involved in the task performed in this study? Explain your answer.
4. The researchers suggested that recognizing a face is easier than recalling a name. Based on what you know about memory from this chapter, why do you think this is the case?

Article Reference: Burton, A. M., Jenkins, R., & Robertson, D. J. (2019). I recognize your name but I can't remember your face: An advantage for names in recognition memory. *Quarterly Journal of Experimental Psychology, 72*, 1847–1854.

Note: Experiment 1 from the article is described here.

Purpose of the Study: In this study, the researchers investigated the saying "I recognize your face, but I can't remember your name." They designed a study to test whether it is true that people forget names more often than they forget faces. The researchers suggested that in most circumstances, one is recognizing a face but recalling a name; overall, recognition is often easier than recall. Based on this difference, they tested memory for names and faces in more equivalent ways to determine if memory for names is, in fact, worse than memory for faces.

Method of the Study: Undergraduate students were shown 40 name–face pairs for unfamiliar names and faces. They were asked to try to remember the people shown, including names and faces. They then completed recognition tests, one for names and one for faces. In each test, half of the names/faces shown were ones that had been studied, and half were new unstudied items. For the studied names, half were shown in the same font style as studied, and half were shown in a different font style. For the studied faces, half were the same photo shown at study, and half were different photos of the same person.

Results of the Study: The results of the study showed that recognition accuracy was higher for the names than for the faces. In addition, accuracy was higher when the format for studied items was the same at study and test than when the format changed (different font style or different photo of the same person).

Conclusions of the Study: These results suggest that memory for faces is lower than that for names when both are tested in a similar way with recognition tests. This is a surprising finding, suggesting that the popular belief that faces are easier to remember than names is an illusion—remembering faces is easier only because you typically can recognize a face but you need to recall a name. This is just one study, and it will need to be replicated in other laboratories, but it certainly gives us something to think about.

KNOWLEDGE CHECK: CHAPTER SUMMARY

(You will find the answers in the Appendix.)

- Memory is defined as the capacity to (1) ______ and (2) ______ information.

Remembering Over the Short Term

- Both (3) ______ and (4) ______ sensory memory retain relatively (5) ______ replicas of an incoming stimulus. With (6) ______ memory, a visual memory or image is retained for about half a second, long enough to help process the incoming message. With (7) ______ memory, a pure sound is held briefly in auditory memory and may help in language processing.
- We use (8) ______-term memory to store and think about information temporarily, usually as an "inner voice." Information in short-term memory is quickly (9) ______ if not rehearsed, because of (10) ______ (passing time) or (11) ______ (from the environment). Memory (12) ______ is equal to the amount of information that can be (13) ______ in about (14) ______ seconds, usually seven plus or minus two items. Memory span can be increased through a method called (15) ______, which involves rearranging information into meaningful patterns. Some researchers have suggested that we have special systems in a "working" memory that handle spatial (visuospatial sketchpad) and verbal (phonological loop) information.

Storing Information for the Long Term

- We recall personal moments with (16) ______ memory. (17) ______ memories are of facts and knowledge about the world. Our knowledge of how to do things is stored in (18) ______ memory.
- (19) ______ has to do with making (20) ______ among experiences, which allows for easier (21) ______ of stored memories. It helps to think about the (22) ______ of an experience, notice (23) ______, and notice similarities to and (24) ______ from existing knowledge. You can also improve retention by forming mental (25) ______, by spacing your (26) ______, and by considering the (27) ______ position of the material.
- Mnemonic devices, which include the method of (28) ______ and the peg- (29) ______ technique, are mental exercises that use visual imagery to help us remember.

Recovering Information From Cues

- Researchers believe the amount of information that can be remembered or retrieved depends on (30) ______. Good retrieval cues usually (31) ______ the way the information was encoded. The (32) ______-appropriate processing principle holds that we should study material with the same kinds of (33) ______ processes that will be used during the (34) ______ process.
- (35) ______ are large clusters of related facts about people, activities, and places. Memory schemas are adaptive but can influence what is remembered and may lead to (36) ______ memories.

- When we remember something without conscious awareness, it's called (37) ______ memory. Prior experience and stored memories may influence implicit memory. We use (38) ______ memory when we make a conscious, deliberate effort to recall something.

Updating Memory

- Ebbinghaus found that (39) ______ forgetting occurs soon after initial exposure to an experience, but (40) ______ forgetting can continue for a long time. Forgetting can be extremely (41) ______, as it prevents our minds from becoming cluttered with useless information: We need to remember where we parked our car today, not yesterday.
- The simple passage of time (decay) isn't sufficient to explain most aspects of forgetting. Equally important are (42) ______ interference, in which (43) ______ material interferes with the recovery of old memories, and (44) ______ interference, in which (45) ______ material interferes with the formation and recovery of new memories.
- Freud believed that the mind may deliberately inhibit or (46) ______ certain memories as a form of self-protection. Most researchers are undecided about the scientific (47) ______ of this concept. We do sometimes forget traumatic events, but it's not clear that this forgetting is due to special processes.
- Forgetting caused by a physical problem is called (48) ______. (49) ______ amnesia is loss of memory for events that happened (50) ______ the accident or disease; (51) ______ amnesia causes events that happened (52) ______ the trauma to be forgotten. Although the (53) ______ is important in forming new memories, no single structure is responsible for the complex processes of memory. Amnesia may be regulated by the amount or production of certain (54) ______.

CRITICAL THINKING QUESTIONS

1. Do you consider the lingering afterimage left by the flash of a camera to be a type of memory?
2. Can you think of a reason it might be adaptive for icons to be lost so quickly?
3. Why do you suppose the telephone company created telephone numbers in three chunks—for example, 888-449-5854?
4. Given what you've learned about repetition and memory, do you think it's a good idea to have children learn arithmetic tables by rote repetition?
5. Do you think all remembering is reconstructive? What about sensory memory—isn't that a pure kind of remembering?
6. Can you think of any ways to lessen the influence of proactive interference? Is there any way that you could study information to prevent interference?

KEY TERMS

amnesia (p. 301)
anterograde amnesia (p. 301)
chunking (p. 277)
cued recall (p. 287)
decay (p. 297)
distinctiveness (p. 281)
distributed practice (p. 282)
echoic memory (p. 273)
elaboration (p. 280)
encoding (p. 270)
episodic memory (p. 279)
explicit memory (p. 293)
flashbulb memories (p. 285)
forgetting (p. 294)
free recall (p. 287)
iconic memory (p. 273)
implicit memory (p. 293)
long-term memory (p. 279)
memory (p. 270)
memory span (p. 276)
method of loci (p. 284)
mnemonic devices (p. 283)

peg-word method (p. 284)
primacy effect (p. 282)
proactive interference (p. 298)
procedural memory (p. 280)
recency effect (p. 282)
rehearsal (p. 275)
repression (p. 298)
retrieval (p. 270)
retroactive interference (p. 298)
retrograde amnesia (p. 301)
schema (p. 291)
semantic memory (p. 280)
sensory memory (p. 272)
short-term memory (p. 272)
storage (p. 270)
transfer-appropriate processing (p. 289)
visual imagery (p. 281)