CHAPTER 8

CHAPTER OUTLINE

1 The Nature of Memory
2 Memory Encoding
3 Memory Storage
4 Memory Retrieval
5 Forgetting
6 Study Tips from the Science of Memory
7 Memory and Health and Wellness

MEMORY

Experiencing Psychology

AKIRA HARAGUCHI AND HIS REMARKABLE MEMORY

On July 2, 2005, the British Broadcasting Company (BBC) reported that a Japanese mental health counselor, Akira Haraguchi, age 59, recited the digits of pi to the number's first 83,431 decimal places, from memory, shattering the previous world record (BBC News, 2005). The recitation took several hours; Haraguchi had to start over after the first 3 hours because he lost his place. Imagine memorizing such a list, over 80,000 numbers long, with no apparent pattern or meaning. Surely Haraguchi's act earns a place in a book of amazing acts of memory. Mnemonists are people who have astonishing memory abilities such as Haraguchi's, and as we will see, psychologists (including positive psychologists) have learned a good deal about memory from such individuals (Takahashi & others, 2006). Consider that the field of positive psychology stresses not only the *very best* of human capacities but also the *extraordinary* aspects of human ability in everyday experience. And daily life presents countless examples that demonstrate the amazing capacity of human memory.

Imagine for example that you are at an upscale restaurant with six friends. The server takes your order. After reciting your rather complicated dinner preferences, you note that he is not writing anything down. Now you wait patiently through your friends' orders and cannot help but wonder, "How can he possibly remember all this?" Surely, you will get blue cheese instead of ranch salad dressing, or a side of carrots instead of green beans, or your pasta will be covered with cheese when you specifically requested no cheese. But when the meal arrives, everything is exactly right. Waiters seem to commit amazing acts of memory routinely. How do they do it? Asked to share their secrets, a few college students who moonlight in food service explained their method: "I always try to remember the person's face, and imagine him eating the food he's ordered"; "The more complicated the order is, the easier it is to remember"; "If it's something really off the wall, you'll never forget it"; "Repetition is the key!" As we will see, these techniques are surprisingly well supported by research on memory.

Memories matter to us in a larger way as well. Recent controversies over the accuracy of memoirs demonstrate that memories have a special place, beyond that of fiction. Memories are a piece of "what really happened," and as such they have an unusual value to us. Even Oprah Winfrey was moved to apologize to her viewers for recommending James Frey's "nonfiction" book, *A Million Little Pieces*, when it was revealed that many of the experiences described were not, in fact, facts.

PREVIEW

Through our memory, we weave the past into the present. Memory can quietly stir, or spin off, with each thought we think and each word we utter. As twentieth-century American playwright Tennessee Williams once remarked, "Life is all memory except for the one present moment that goes by so quick you can hardly catch it going." In this chapter, we explore three key aspects of memory: how information gets into our memory, how we store the information, and how we retrieve it. We also examine fascinating aspects of why we sometimes forget something, what the science of memory can tell us about improving our study habits, and how memory might even be involved in our health and wellness.

1 The Nature of Memory

Identify the three phases of memory.

The stars are shining, and the moon is full. A beautiful evening is coming to a close. You look at your significant other and think, "I'll never forget this night." How is it possible that, in fact, you never will? Years from now, you might even tell your children about that one special night so many years ago, even if you had not thought about it in the years since. How does one perfect night become a part of our enduring life memories?

Psychologists define **memory** as the retention of information or experience over time. Memory occurs through three important processes: encoding, storage, and retrieval. For memory to work, we have to take in information (encode the sights and sounds of that night), store it or represent it in some manner (retain it in some mental storehouse), and then retrieve it for a later purpose (recall it when someone asks, "So how did you two end up together?"). The first three sections of the chapter focus on these phases of memory: encoding, storage, and retrieval (Figure 8.1).

Except for the annoying moments when our memory fails, or the situation where someone we know experiences memory loss, we do not think about how much everything we do or say depends on the smooth operation of our memory systems (Schacter, 1996, 2001, 2007; Schacter & Addis, 2007). Let's return to our server in the restaurant. He has to attend to the orders he receives—who is asking for what and how they would like it prepared. To do so, he must encode the information about each customer and each order. He might look at each customer and associate his or her face with the menu items requested. Without writing anything down, he must retain the information, at least until he gets the orders to the kitchen or onto the computer. He might rehearse the order over in his mind as he walks to the back of the restaurant. When delivering the food to the table, he must accurately retrieve the information about who ordered what. Human memory systems truly are remarkable when you think of how much information we put into our memories and how much we must retrieve to perform all of life's activities (Kellogg, 2007).

memory The retention of information over time through encoding, storage, and retrieval.

encoding The way in which information gets into memory storage.

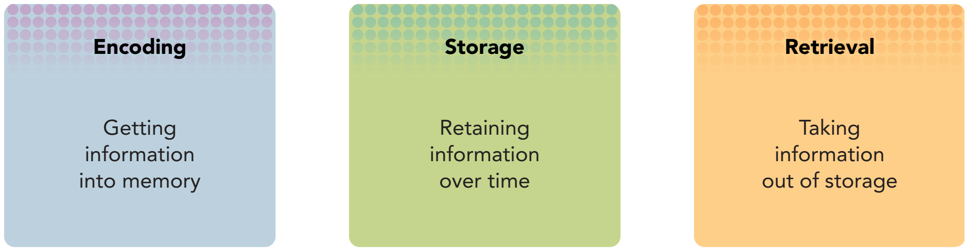


FIGURE 8.1

Processing Information in Memory As you read about the many aspects of memory in this chapter, think about the organization of memory in terms of these three main activities.

REVIEW AND SHARPEN YOUR THINKING

1 Identify the three phases of memory.

- Define memory and briefly profile the three phases of memory.

Imagine what life would be like without memory. Reflect on the activities you have engaged in today. When and how did memory influence your daily life? Think about what memory means with respect to social relationships. What does it mean to you if someone remembers your name—or does not remember it?

2 Memory Encoding

Explain how memories are encoded.

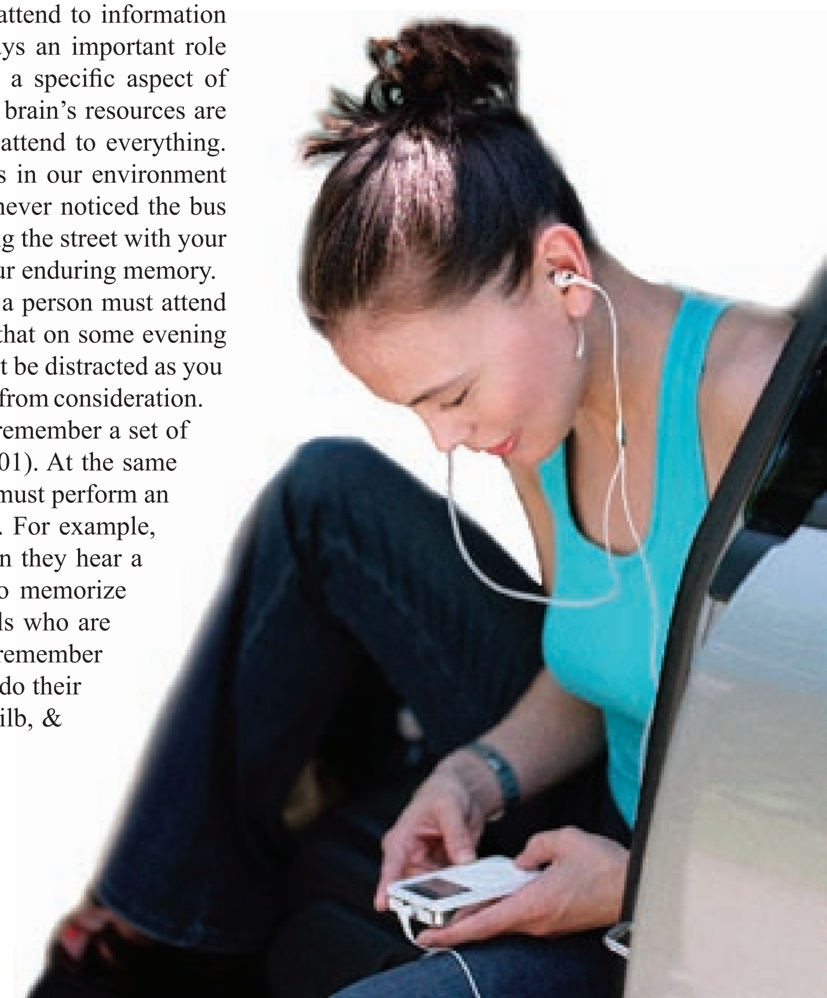
Encoding is the way in which information is processed for storage in memory. When you are listening to a lecture, watching a movie, enjoying music on your iPod, or talking with a friend, you are encoding information into memory. In everyday experiences, encoding has much in common with learning.

Some information gets into memory virtually automatically, whereas receiving other information takes effort. Let's examine some of the encoding processes that require effort. The issues that interest psychologists include how effectively we attend to information, how deeply we process it, how extensively we elaborate it with details, and how much we use mental imagery to encode it.

Attention

Clearly, we cannot consciously remember something that we never saw, never heard, or never felt. To begin the process of memory encoding, we have to attend to information (Posner & Rothbart, 2007). As we saw in Chapter 5, attention plays an important role in perception. Recall that selective attention involves focusing on a specific aspect of experience while ignoring others. Attention is selective because the brain's resources are limited. Although our brains are remarkably efficient, they cannot attend to everything. Limitations mean that we have to attend selectively to some things in our environment and ignore others (Knudsen, 2007). So, on that special night, you never noticed the bus that roared past or the people who passed you while you strolled along the street with your significant other. Those aspects of that night will not make it into your enduring memory.

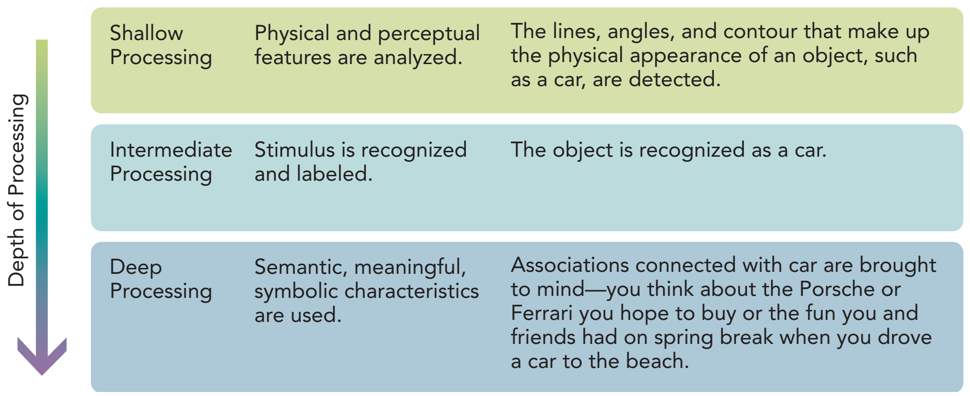
Divided attention also affects memory encoding. It occurs when a person must attend to several things simultaneously (Savage & others, 2006). Imagine that on some evening you are thinking about a difficult problem at work and cannot help but be distracted as you ponder possible solutions. Suddenly, even the moon and the stars drop from consideration. This effect has been studied by researchers who ask participants to remember a set of items, such as a list of words or the details of a story (Schacter, 2001). At the same time that they are trying to encode this information, the participants must perform an additional task that draws their attention away from the initial task. For example, they might be required to monitor a series of tones and report when they hear a low- or high-pitched tone, at the same time that they are trying to memorize the list of words or a story. In a number of such studies, individuals who are allowed to give their full attention to information they are asked to remember do much better on subsequent memory tests of the information than do their counterparts who experience divided attention (Naveh-Benjamin, Kilb, & Fisher, 2006; Pomplum, Reingold, & Shen, 2001).



Listening to music on your iPod involves encoding—processing those tunes for storage in your memory.

FIGURE 8.2

Depth of Processing According to the levels of processing principle, deeper processing of stimuli produces better memory of them.



Levels of Processing

Attention alone does not completely explain the encoding process. For example, if you pay attention to the word *boat*, you might process the word at three different levels. At the shallowest level, you might notice the shapes of the letters; at an intermediate level, you might think of characteristics of the word (such as that it rhymes with *coat*); and at the deepest level, you might think about the kind of boat you would like to own and the last time you went fishing.

This model of the encoding process was proposed by Fergus Craik and Robert Lockhart (1972). The concept of **levels of processing** refers to the idea that encoding occurs on a continuum from shallow to deep, with deeper processing producing better memory (Figure 8.2).

- *Shallow level:* The sensory or physical features of stimuli are analyzed. For instance, we might detect the lines, angles, and contours of a printed word's letters or detect a sound's frequency, duration, and loudness (recall the discussion of feature detection in Chapter 5).
- *Intermediate level:* The stimulus is recognized and given a label. For example, we identify a four-legged barking object as a dog.
- *Deepest level:* Information is processed semantically, in terms of its meaning. At this deepest level, we make associations. We might associate the barking dog with a warning of danger or with good times, such as playing fetch with a pet. The more associations we make, the deeper the processing (Ragland & others, 2006).

A number of studies have shown that people's memories improve when they make associations to stimuli and use deep processing, as opposed to attending only to the physical aspects of the stimuli and using shallow processing (Howes, 2006). For example, researchers have found that, if you encode something meaningful about a face and make associations with it, you are more likely to remember it (Harris & Kay, 1995). So, our server who strives to remember the face of the customer and to imagine her eating the food she has ordered is using deep processing. You might attach meaning to the face of a person in your introductory psychology class by noting that she reminds you of someone you have seen on TV, and you might associate her face with your psychology class.

Elaboration

Cognitive psychologists have recognized that good encoding of a memory depends on more than just depth of processing. Within deep processing, the more extensive the processing, the better the memory (Kellogg, 2007). **Elaboration** is the extensiveness of processing at any given level. For example, rather than memorizing the definition of *memory*, you would do better to learn the concept of memory by coming up with examples of how information enters your mind, how it is stored, and how you can retrieve it. Thinking of examples of a concept is a good way to understand it. Self-reference is another effective way to elaborate information (Czienskowski & Giljohann, 2002; Hunt & Ellis, 2004) (Figure 8.3). For example, if the word *win* is on a list of words to remember, you might think of the last time you won a bicycle race; or if the word *cook* appears, you might recall the last time you made dinner. In general, deep elaboration—elaborate processing of meaningful information—is an excellent way to remember.

One reason that elaboration produces good memory is that it adds to the *distinctiveness* of "memory codes" (Ellis, 1987). By elaborating on an experience, we create a highly unique representation of it in memory. If we think of remembering as searching for a particular bit of information, the more distinctive an experience, the easier it will be to find in the mental storehouse of memory. To remember a piece of information such as a name, an experience, or a fact about geography, you need to search for the code that contains this information among the mass of codes contained in long-term memory.

The search process is easier if the memory code is somehow unique (Hunt & Kelly, 1996). The situation is not unlike searching for a friend at a crowded airport. If that friend is 6 feet tall and has flaming red hair, she will be easier to find than a friend who is 5 feet 5 inches tall with brown hair. Similarly, highly distinctive memory codes can be more easily differentiated. Importantly, while the value of distinctiveness here is most apparent at remembering (that is, during retrieval), the creation of a distinctive memory occurs at encoding. Also, as encoding becomes more elaborate, more information is stored. And as more information is stored, the more likely it is that the code will be distinctive—that is, easy to differentiate from other memory codes. For example, if you meet someone with whom you hope to become better friends someday, you will do a better job of remembering his name if you initially encode a lot of information about him, such as his appearance, occupation, and something he has said. You are more likely to remember him than someone who encodes him only as "blond."

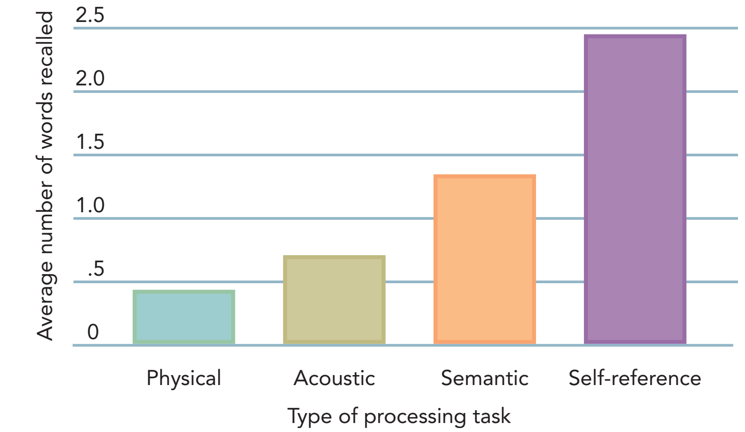


FIGURE 8.3

Memory Improves When Self-Referencing Is Used In one study, researchers asked participants to remember lists of words according to the words' physical, acoustic (sound), semantic (meaning), or self-referent characteristics. As can be seen, when individals generated self-references for the words, they remembered them better.

The process of elaboration is also evident in the physical activity of the brain. Neuroscience research has shown a link between elaboration during encoding and brain activity (Kirchhoff & Buckner, 2006; Kirchhoff, Schapiro, & Buckner, 2005). In one study, individuals were placed in magnetic resonance imaging (MRI) machines (see Chapter 3), and one word was flashed every 2 seconds on a screen inside (Wagner & others, 1998). Initially, the individuals simply noted whether the words were in uppercase or lowercase letters. As the study progressed, they were asked to determine whether each word was concrete, such as *chair* or *book*, or abstract, such as *love* or *democracy*. In this study, the participants showed more neural activity in the left frontal lobe of the brain during the "concrete/abstract" task than they did when they were asked merely to state whether the words were uppercase or lowercase. And they demonstrated better memory in the concrete/abstract task. The researchers concluded that greater elaboration of information is linked with neural activity, especially in the brain's left frontal lobe, and with improved memory.

Imagery

One of the most powerful ways to make memories distinctive is to use mental imagery (Murray, 2007; Quinn & McConnell, 2006). Psychologist Alexander Luria (1968) chronicled the life of S., whose unique visual imagination allowed him to remember an extraordinary amount of detail. Luria had become acquainted with S. in the 1920s in Russia. Luria began with some simple research to test S.'s memory. For example, he asked S. to recall a series of words or numbers, a standard method of testing memory skills. Luria concluded that S. had no apparent limits to his ability to recall. In such tests, people remember at most five to nine numbers. Not only could S. remember as many as 70 numbers, but he could also recall them accurately in reverse order. S. moreover could report the sequence flawlessly with no warning or practice even as long as 15 years after his initial exposure to the sequence. In addition, after the 15-year interval, S. could describe what Luria had been wearing and where he had been sitting when S. learned the

levels of processing The idea that encoding occurs on a continuum from shallow to deep, with deeper processing producing better memory.

elaboration Extensiveness of processing at any given level of memory.

list. Similar feats of recall included accurately reproducing passages from languages he did not know—after hearing the passage only once! How could S. manage such tasks? As long as each number or word was spoken slowly, S. could represent it as a visual image that was meaningful to him. These images were durable—S. easily remembered the image he created for each sequence long after he learned the sequence. Imagery helped S. remember complicated lists of items and information. For example, S. once was asked to remember the following formula:

[COMP: INSERT EQUATION HERE--SEE P. 310 OF PREVIOUS EDITION FOR EQUATION]

storage Retention of information over time and the representation of information in memory.

Atkinson-Shiffrin theory The view that memory involves three separate systems: sensory memory, short-term memory, and long-term memory.

sensory memory Information from the world that is held in its original form only for an instant, not much longer than the brief time it is exposed to the visual, auditory, and other senses.

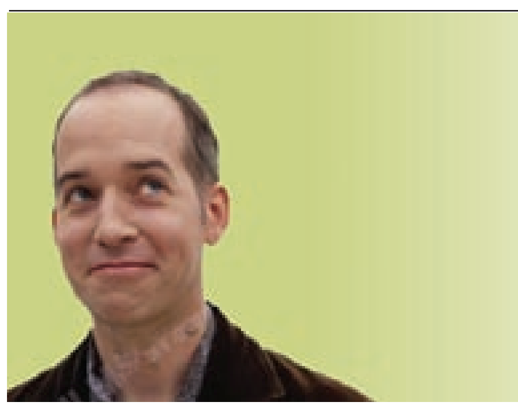
S. studied the formula for 7 minutes and then reported how he memorized it. Notice in his account of this process, which follows, how he used imagery:

> Neiman (*N*) came out and jabbed at the ground with his cane (·). He looked up at a tall tree, which resembled the square-root sign (√), and thought to himself: "No wonder this tree has withered and begun to expose its roots. After all, it was here when I built these two houses" (d^2). Once again he poked his cane (·). Then he said: "The houses are old, I'll have to get rid of them; the sale will bring in far more money." He had originally invested 85,000 in them (85). . . . (Luria, 1968)

S.'s complete story was four times this length. But the imagery in the story he created must have been powerful, because S. remembered the formula perfectly 15 years later without any advance notice.

S. certainly represents an extreme case of amazing *mnemonic* ability—that is, skill in remembering. But imagery functions as a powerful tool for encoding. Recall that one of our student waiters mentioned imagining the person eating the food to remember the customer's order. Classic studies by Allan Paivio (1971, 1986, 2007) documented how imagery can improve memory. Paivio argues that memory is stored in one of two ways: as a verbal code (a word or a label) or as an image code. Paivio thinks that the image code, which is highly detailed and distinctive, produces better memory. His *dual-code hypothesis* claims that memory for pictures is better than memory for words because pictures—at least those that can be named—are stored both as image codes and as verbal codes. Thus we have two potential avenues by which information can be retrieved.

REVIEW AND SHARPEN YOUR THINKING



2 Explain how memories are encoded.

- Summarize how attention is involved in memory.
- Describe the levels of processing involved in memory.
- Discuss elaboration.
- Know about the role of imagery in memory.

Think of a common object or location that you see every day (for example, your backpack or a building you pass daily) but that is not currently in your sight. Draw the object or location. Later compare your results with the real thing. What differences do you notice? Does what you learned about encoding help to explain the differences?

3 Memory Storage

Discuss how memories are stored.

The quality of encoding does not alone determine the quality of memory. A memory also needs to be stored properly after it is encoded. **Storage** encompasses how information is retained over time and how it is represented in memory.

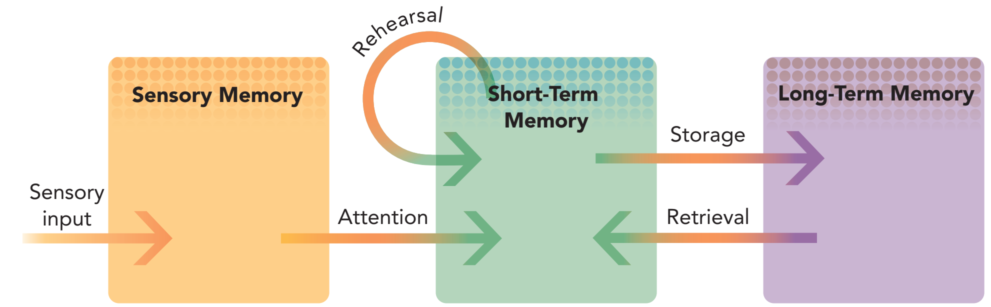


FIGURE 8.4
Atkinson and Shiffrin's Theory of Memory In this model, sensory input goes into sensory memory. Through the process of attention, information moves into short-term memory, where it remains for 30 seconds or less, unless it is rehearsed. When the information goes into long-term memory storage, it can be retrieved over the lifetime.

We remember some information for less than a second, some for half a minute, and some for minutes, hours, years, or even a lifetime. Richard Atkinson and Richard Shiffrin (1968) formulated an early popular theory of memory that acknowledged the varying life span of memories (Figure 8.4). The **Atkinson-Shiffrin theory** states that memory storage involves three separate systems:

- *Sensory memory:* time frames of a fraction of a second to several seconds
- *Short-term memory:* time frames up to 30 seconds
- *Long-term memory:* time frames up to a lifetime

As you read about these three memory storage systems, you will find that time frame is not the only thing that makes them different from one another. Each type of memory operates in a distinctive way and has a special purpose.

Sensory Memory

Sensory memory holds information from the world in its original sensory form for only an instant, not much longer than the brief time it is exposed to the visual, auditory, and other senses (Deouell & others, 2006). Sensory memory is very rich and detailed, but the information in it is quickly lost unless certain processes are engaged in that transfer it into short-term or long-term memory.

Think about all the sights and sounds you encounter as you walk to class on a typical morning. Literally thousands of stimuli come into your field of vision and hearing—cracks in the sidewalk, chirping birds, a noisy motorcycle, the blue sky, faces of hundreds of people. You do not process all of these stimuli, but you do process a number of them. In general, you process many more stimuli at the sensory level than you consciously notice. Sensory memory retains this information from your senses, including a large portion of what you think you ignore.

But sensory memory does not retain the information very long. *Echoic memory* (from the word *echo*) is the name given to auditory sensory memory, which is retained for up to several seconds. Imagine standing in an elevator with a friend who suddenly asks, "What was that song?" about the music that was being piped in. If your friend has asked his question quickly enough, you just might have a trace of the tune left on your sensory registers. *Iconic memory* (from the word *icon*, which means "image") is the name given to visual sensory memory, which is retained only for about one-fourth of a second (Figure 8.5). Visual sensory memory is responsible for our ability to "write" in the air using a sparkler on the 4th of July—the residual iconic memory is what makes a moving point of light appear to be a line. The sensory memory for other senses, such as smell and touch, has received little attention in research studies.

The first scientific research on sensory memory focused on iconic memory. In George Sperling's (1960) classic study, participants were presented with patterns of stimuli such as those in Figure 8.6. As you look at the letters, you have no trouble recognizing them. But Sperling flashed the letters on a screen for very brief intervals, about 1/20 of a second. After a pattern was flashed on the screen, the participants could report only four or five letters. With such short exposure, reporting all nine letters was impossible.

Some of the participants in Sperling's study reported feeling that, for an instant, they could see all nine letters within a briefly flashed pattern. But they ran into trouble when they

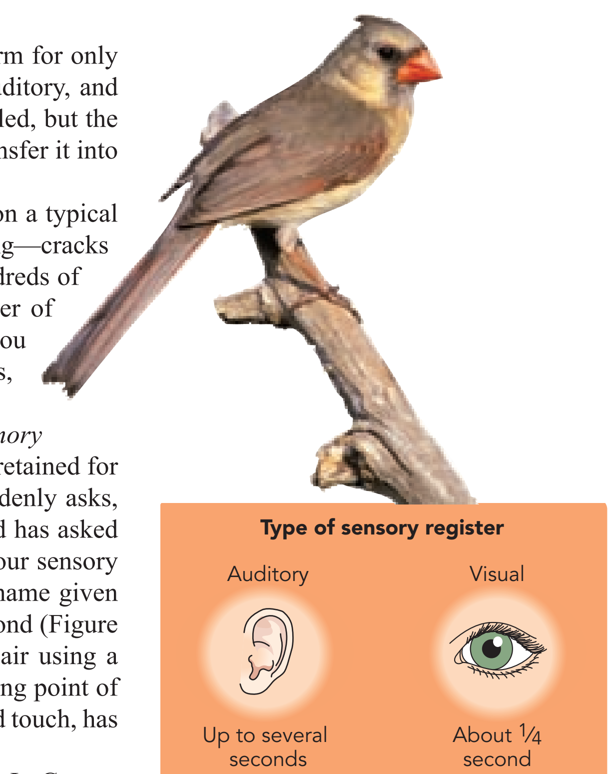


FIGURE 8.5
Auditory and Visual Sensory Memory If you hear this bird's call while walking through the woods, your auditory sensory memory holds the information for several seconds. If you see the bird, your visual sensory memory holds the information for only about 1/4 of a second.

FIGURE 8.6

Sperling's Sensory Memory Experiment This array of stimuli is similar to those flashed for about 1/20 of a second to the participants in Sperling's study.

tried to name all the letters they had initially *seen*. One hypothesis to explain this experience is that all nine letters were initially processed as far as the iconic sensory memory level. This is why all nine letters were *seen*. However, forgetting from iconic memory was so rapid that the participants did not have time to transfer all the letters to short-term memory, where they could be named.

Sperling reasoned that, if all nine letters are actually processed in sensory memory, they should all be available for a brief time. To test this possibility, Sperling sounded a low, medium, or high tone just after a pattern of letters was shown. The participants were told that the tone was a signal to report only the letters from the bottom, middle, or top row. Under these conditions, the participants performed much better, and this outcome suggests a brief memory for most or all of the letters in the display.

Short-Term Memory

Much information goes no further than the stage of sensory memory of sounds and sights. This information is retained for only a brief instant. However, some of the information, especially that to which we pay attention, is transferred to short-term memory. **Short-term memory** is a limited-capacity memory system in which information is usually retained for only as long as 30 seconds unless strategies are used to retain it longer. Compared with sensory memory, short-term memory is limited in capacity, but it can store information for a longer time.

The limited capacity of short-term memory was examined by George Miller (1956) in the classic paper "The Magical Number Seven, Plus or Minus Two." Miller pointed out that on many tasks individuals are limited in how much information they can keep track of without external aids. Usually the limit is in the range of 7 + 2 items. The most widely cited example of the 7 + 2 phenomenon involves *memory span*, which is the number of digits an individual can report back in order after a single presentation of them. Most college students can remember 8 or 9 digits without making errors (think about how easy it is to remember a phone number, for instance). Longer lists pose problems because they exceed short-term memory capacity. If you rely on simple short-term memory to retain longer lists, you probably will make errors.

Chunking and Rehearsal Two ways to improve short-term memory are chunking and rehearsal. *Chunking* involves grouping or "packing" information that exceeds the 7 + 2 memory span into higher-order units that can be remembered as single units. In essence, chunking is a form of memory encoding: specifically, elaboration. It works by making large amounts of information more manageable (Gobet & Clarkson, 2004).

For an example of chunking, consider this list: *hot, city, book, forget, tomorrow,* and *smile*. Try to hold these words in memory for a moment; then write them down. If you recalled the words, you succeeded in holding 30 letters, grouped into six chunks, in memory. Now hold the following in memory and then write it down:

O LDH ARO LDAN DYO UNGB EN

How did you do? Do not feel bad if you did poorly. This string of letters is very difficult to remember, even though it is arranged in chunks. However, if you chunk the letters to form the meaningful words "Old Harold and Young Ben," they become much easier to remember.

Another way to improve short-term memory involves *rehearsal*, the conscious repetition of information (Bunting, Cowan, & Scott Saults, 2006). Information stored in short-term memory lasts half a minute or less without rehearsal. However, if rehearsal is not interrupted, information can be retained indefinitely. Rehearsal is often verbal, giving the impression of an inner voice, but it can also be visual or spatial, giving the impression of a private inner eye (Pearson, 2006). One way to use your visualization skills is to retain the appearance of an object or a scene for a period of time after you have viewed it. People who are unusually good at this task are said to have *eidetic imagery*, or a photographic memory. All of us can retain images to some degree, but a small number of us may be so good at preserving an image that, for example, we literally "see" the page of a textbook as we try to remember

short-term memory A limited-capacity memory system in which information is retained for only as long as 30 seconds unless strategies are used to retain it longer.

working memory A three-part system that temporarily holds information as people perform cognitive tasks. Working memory is a kind of mental "workbench" on which information is manipulated and assembled to help individuals perform other cognitive tasks.

information during a test. However, true eidetic imagery is so rare it has been difficult to study; some psychologists even doubt its existence (Gray & Gummerman, 1975).

Rehearsal works best when we must briefly remember a list of numbers or items such as orders on a menu. When we need to remember information for longer periods of time, as when we are studying for a test coming up next week or even an hour from now, other strategies usually work better. A main reason rehearsal does not work well for retaining information over the long term is that rehearsal often involves just mechanically repeating information, without imparting meaning to it. The fact that, over the long term, we remember information best when we add meaning to it demonstrates the importance of deep, semantic processing.

Working Memory Some experts believe that Atkinson and Shiffrin's theory of the three time-linked memory systems is too simplistic (Baddeley, 2006, 2007). They believe that memory does not always work in a neatly packaged three-stage sequence, and they think that both short-term and long-term memory are far more complex and dynamic. For example, some experts think that short-term memory uses long-term memory's contents in more flexible ways than simply retrieving information from it (Murdock, 1999). And they believe that short-term memory involves far more than rehearsal and passive storage of information. We now examine the working-memory view of short-term memory.

British psychologist Alan Baddeley (1993, 1998, 2001, 2003, 2006, 2007) proposed the concept of **working memory,** a three-part system that temporarily holds information as people perform cognitive tasks. Working memory is a kind of mental "workbench" on which information is manipulated and assembled to help us comprehend written and spoken language, make decisions, and solve problems. If all of the information in your computer is like long-term memory, then working memory might be compared to what you have open on your computer desktop. Note that working memory is not like a passive storehouse with shelves to store information until it moves to long-term memory. Rather, it is an active memory system (Gathercole, 2007; Hitch, 2006).

Figure 8.7 shows Baddeley's view of the three components of working memory. Think of them as an executive (the central executive) who has two assistants (the phonological loop and visuospatial working memory) to help do the work.

1. The *phonological loop* is specialized to briefly store speech-based information about the sounds of language. The phonological loop contains two separate components: an acoustic code, which decays in a few seconds, and rehearsal, which allows individuals to repeat the words in the phonological store.
2. *Visuospatial working memory* stores visual and spatial information, including visual imagery (Repovs & Baddeley, 2006). Visuospatial working memory also has been called the *visuospatial scratch pad*. As in the case of the phonological loop, the capacity of visuospatial working memory is limited. For example, if you try to put too many items in visuospatial working memory, you cannot represent them accurately enough to retrieve them successfully. The phonological loop and visuospatial memory function independently. You could rehearse numbers in the phonological loop while making spatial arrangements of letters in visuospatial working memory.
3. The *central executive* integrates information not only from the phonological loop and visuospatial working memory but also from long-term memory. In Baddeley's (2006, 2007) view, the central executive plays important roles in attention, planning, and organizing. The central executive acts much like a supervisor who monitors which information and issues deserve attention

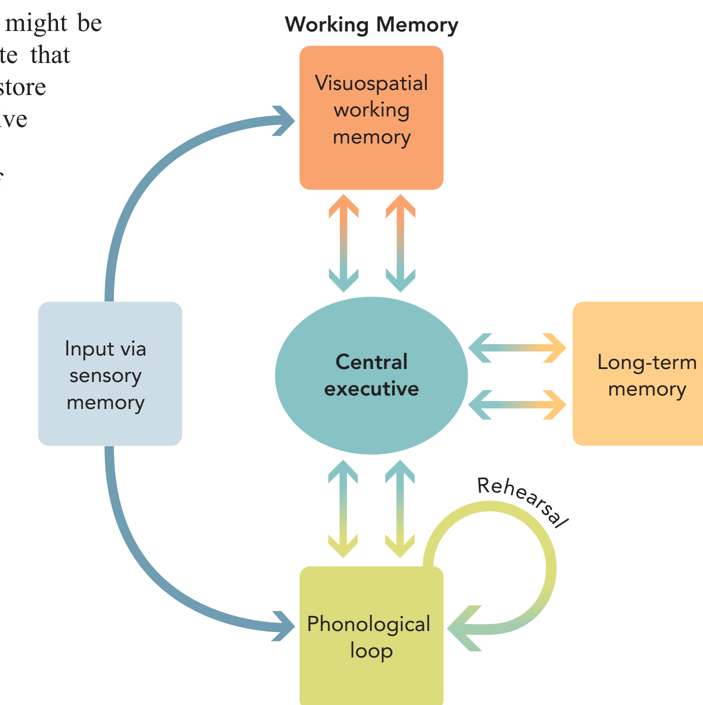
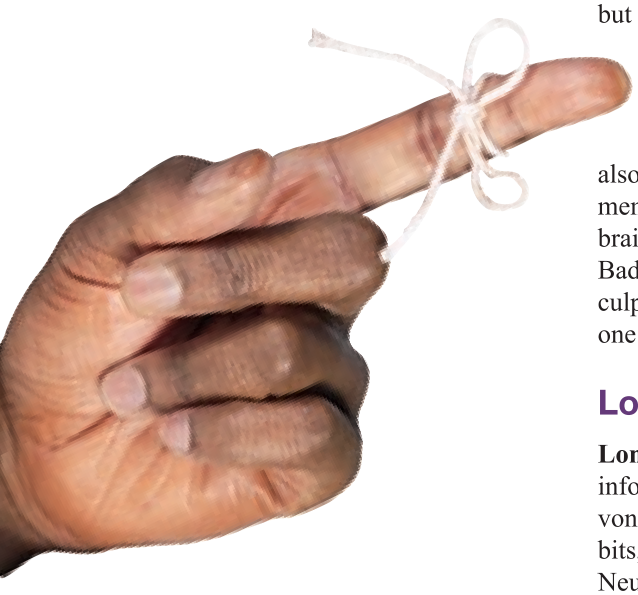


FIGURE 8.7

Working Memory In Baddeley's working-memory model, working memory is like a mental workbench where a great deal of information processing is carried out. Working memory consists of three main components: The phonological loop and visuospatial working memory serve as assistants, helping the central executive do its work. Input from sensory memory goes to the phonological loop, where information about speech is stored and rehearsal takes place, and to visuospatial working memory, where visual and spatial information, including imagery, is stored. Working memory is a limited-capacity system, and information is stored there for only a brief time. Working memory interacts with long-term memory, using information from long-term memory in its work and transmitting information to long-term memory for longer storage.

and which should be ignored. It also selects which strategies to use to process information and solve problems. As with the other two components of working memory—phonological loop and visuospatial working memory—the central executive has a limited capacity.

The concept of working memory can help us understand how brain damage influences cognitive skills (Cicerone & others, 2006; Wood & Rutterford, 2006). For example, some types of amnesiacs (individuals with memory loss) perform well on working-memory tasks but not on long-term memory tasks. Another group of patients have normal long-term memory abilities yet do very poorly on working-memory tasks. One such patient has good long-term memory despite having a memory span of only two digits (Baddeley, 1992). The phonological loop was the source of this patient's memory problem. Because he could not maintain verbal codes in the loop, his memory span suffered. He also had difficulty learning new associations between words and nonsense sounds. Working-memory deficits also are involved in Alzheimer disease—a progressive, irreversible brain disorder in older adults that we considered in Chapter 4 (Levinoff & others, 2006). Baddeley (2006, 2007) believes the central executive of the working-memory model is the culprit—Alzheimer patients have great difficulty coordinating different mental activities, one of the central executive's functions.



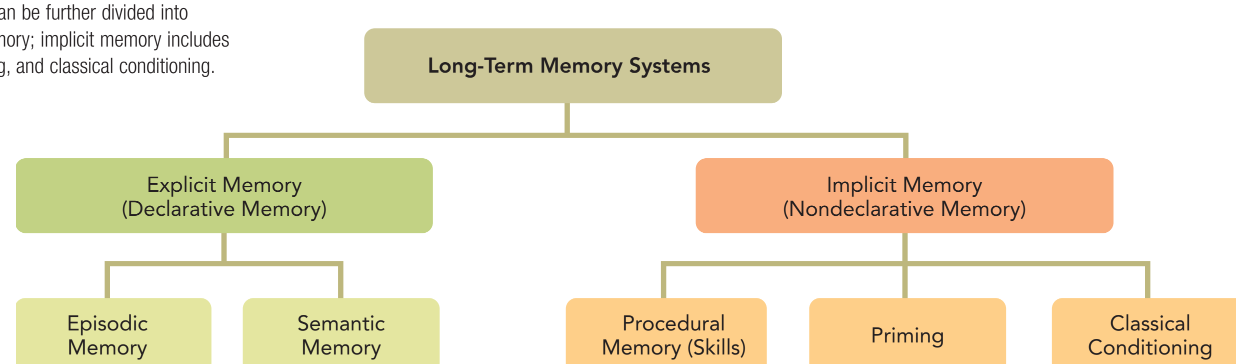
Long-Term Memory

Long-term memory is a relatively permanent type of memory that stores huge amounts of information for a long time. The capacity of long-term memory is indeed staggering. John von Neumann, a distinguished computer scientist, put the size at 2.8 3 10^{20} (280 quintillion) bits, which in practical terms means that our storage capacity is virtually unlimited. Von Neumann assumed that we never forget anything; but even considering that we do forget things, we can hold several billion times more information than a large computer.

Long-term memory is complex, as Figure 8.8 shows. At the top level, it is divided into substructures of explicit memory and implicit memory. Explicit memory can be further subdivided into episodic and semantic memory. Implicit memory includes the systems involved in procedural memory, classical conditioning, and priming.

In simple terms, explicit memory has to do with remembering who, what, where, when, and why; implicit memory has to do with remembering how. To explore the distinction, let's look at a person known as H. M. He had a severe case of epilepsy and underwent surgery in 1953 that involved removing the hippocampus and a portion of the temporal lobes of both hemispheres in his brain. (We examined the location and functions of these areas of the brain in Chapter 3.) His epilepsy improved, but something devastating happened to his memory. Most dramatically, he developed an inability to form new memories that outlive working memory. H. M.'s memory time frame is only a few minutes at most, so he lives, as he has done since 1953, in a perpetual present and cannot remember past events (explicit memory). In contrast, his memory of how to do things (implicit memory) was less affected. For example, he can learn new physical tasks. In one such task, H. M. was asked to trace the outline of a star-shaped figure while he was able to view the figure and his hand only through a mirror. This is a task that most people find difficult in the beginning. Over 3 days of training, H. M. learned this task as effectively and rapidly as normal individuals. On the second and third days, he began at the level he had achieved the previous day (a success in implicit memory), even though he was completely unaware that he had previously practiced the task (a failure in explicit memory). H. M.'s situation clearly demonstrates a distinction between explicit memory, which was dramatically impaired in his case, and implicit memory, which in his case was less influenced by his surgery.

FIGURE 8.8
Systems of Long-Term Memory
Long-term memory stores huge amounts of information for long periods of time, much like a computer's hard drive. The hierarchy in the figure shows the division of long-term memory at the top level into explicit memory and implicit memory. Explicit memory can be further divided into episodic and semantic memory; implicit memory includes procedural memory, priming, and classical conditioning.



We now explore the subsystems of explicit and implicit memory. After we examine these basic structures, we survey the theories developed to explain how they are organized. We also look at recent discoveries in neuroscience that shed light on where in the brain memory is stored.

Explicit Memory **Explicit memory (declarative memory)** is the conscious recollection of information, such as specific facts or events and, at least in humans, information that can be verbally communicated (Tulving, 1989, 2000). Examples of using explicit, or declarative, memory include recounting the events in a movie you have seen and describing a basic principle of psychology to someone.

How long does explicit memory last? Remember that explicit memory includes things you are learning in your classes even now. Will it stay with you? Research by Harry Bahrick has examined this very question. Ohio Wesleyan University, where Bahrick is a professor of psychology, is a small (about 1,800 students) liberal arts school that boasts very loyal alumni who faithfully return to campus for reunions and other events. Bahrick (1984) took advantage of this situation to undertake an ingenious study on the retention of course material over time. He gave vocabulary tests to individuals who had taken Spanish in college as well as to a control group of college students who had not taken Spanish in college. The individuals chosen for the study had used Spanish very little since their college courses. Some individuals were tested at the end of an academic year (just after having taken the courses), but others were tested years after graduation—as many as 50 years later. When how much had been forgotten was assessed, a striking pattern of results emerged (Figure 8.9). Essentially, forgetting tended to occur in the first 3 years after taking the classes and then leveled off, such that adults maintained considerable knowledge of Spanish vocabulary words up to 50 years later.

Bahrick (1984) assessed not only how long ago adults studied Spanish, but also how well they did in their Spanish courses during college. Those who got an *A* 50 years earlier remembered more Spanish than adults who got a *C* when taking Spanish only 1 year earlier! Thus, how well students initially learned the material was even more important than how long ago they studied it.

Bahrick (2000) suggests that such long-term retention of information might be characterized as *permastore* content. This memory is essentially that portion of original learning that appears destined to be with the person virtually forever, even without rehearsal. In addition to focusing on course material, Bahrick and colleagues (1974) have probed adults' memories for the faces and names of their high school classmates. Thirty-five years after graduation, the participants visually recognized 90 percent of the portraits of their high school classmates, with name recognition being almost as high. These results held even in relatively large classes (the mean class size in the study was 294).

What might predict such astonishing long-term memory? At least part of the story lies in how this information is encoded. Bahrick has found that gradual learning is the key. That is, acquiring a language or any skill might be facilitated by learning over the course of several sessions spaced apart rather than all at once. These findings suggest the relevance of basic memory research to learning course material.

Canadian cognitive psychologist Endel Tulving (1972, 1989, 2000) has been the foremost advocate of distinguishing between two subtypes of explicit memory: episodic and semantic. **Episodic memory** is the retention of information about the where, when, and what of life's happenings. It is autobiographical. For example, episodic memory includes the details of where you were when your younger brother or sister was born; what happened on your first date; what you were doing when you heard of the terrorist attacks of September 11, 2001; and what you had for breakfast this morning.

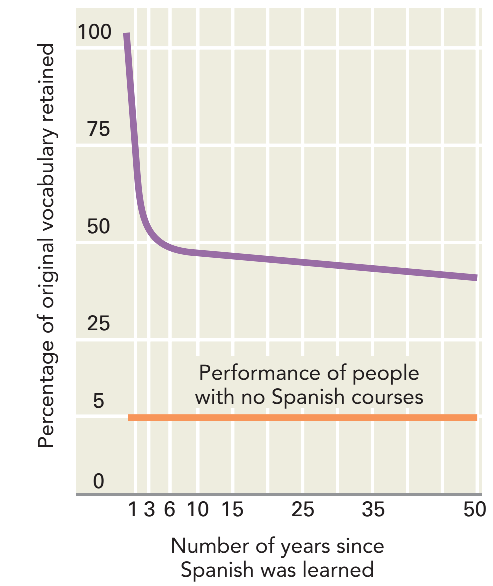


FIGURE 8.9
Memory for Spanish as a Function of Age Since Spanish Was Learned
An initial steep drop over about a 3-year period in remembering the vocabulary learned in Spanish classes occurred. However, there was a little dropoff in memory for Spanish vocabulary from 3 years after taking Spanish classes to 50 years after taking them. Even 50 years after taking Spanish classes, individuals still remembered almost 50 percent of the vocabulary.

long-term memory A relatively permanent type of memory that stores huge amounts of information for a long time.

explicit memory (declarative memory) The conscious recollection of information, such as specific facts or events and, at least in humans, information that can be verbally communicated.

episodic memory The retention of information about the where, when, and what of life's happenings.

Characteristic	Episodic Memory	Semantic Memory
Units	Events, episodes	Facts, ideas, concepts
Organization	Time	Concepts
Emotion	More important	Less important
Retrieval process	Deliberate (effortful)	Automatic
Retrieval report	"I remember"	"I know"
Education	Irrelevant	Relevant
Intelligence	Irrelevant	Relevant
Legal testimony	Admissible in court	Inadmissible in court

FIGURE 8.10
Some Differences Between Episodic and Semantic Memory
These characteristics have been proposed as the main ways to differentiate episodic from semantic memory.

Semantic memory is a person's knowledge about the world. It includes your areas of expertise, general knowledge of the sort you are learning in school, and everyday knowledge about the meanings of words, famous individuals, important places, and common things. For example, semantic memory is involved in a person's knowledge of chess, of geometry, and of who Martin Luther King, Jr., Laura Bush, and Russell Crowe are. An important aspect of semantic memory is that it appears to be independent of an individual's personal identity with the past. You can access a fact—such as that Lima is the capital of Peru—and not have the foggiest notion of when and where you learned it.

Some examples help to clarify the distinction between episodic and semantic memory. Your memory of your first day on campus involves episodic memory. If you take a history class, your memory of the information you need to know to do well on the next test involves semantic memory.

Consider also that, in a certain type of amnesiac state, a person might forget entirely who she is—her name, family, career, and all other information about herself—yet she can talk and demonstrate general knowledge about the world (Rosenbaum & others, 2005). Her episodic memory is impaired, but her semantic memory is functioning. Tulving (1989) reported an especially dramatic case of this type: a young man named K. C. After suffering a motorcycle accident, K. C. lost virtually all use of his episodic memory. The loss was so profound that he was unable to recollect consciously a single thing that had ever happened to him. At the same time, K. C.'s semantic memory was sufficiently preserved that he could learn about his past as a set of facts, just as he would learn about another person's life. He could report, for example, that the saddest day of his life was when his brother drowned about 10 years before. But further questioning revealed that K. C. had no conscious memory of the event. He simply knew about the drowning because he was able to recall—apparently through use of his semantic memory—what he had been told about his brother by other members of his family.

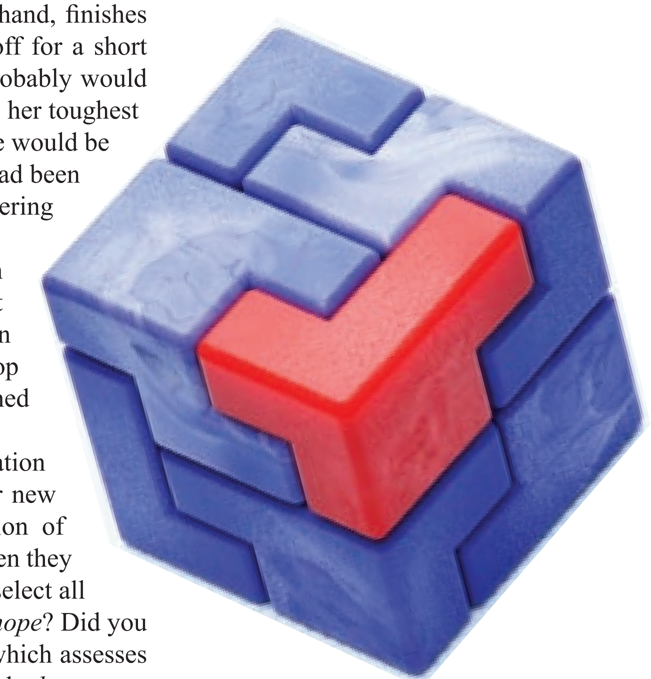
Figure 8.10 summarizes some aspects of the episodic/semantic distinction. The differences that are listed are controversial. One criticism is that many cases of explicit, or declarative, memory are neither purely episodic nor purely semantic but fall in a gray area in between. Consider your memory for what you studied last night. You probably added knowledge to your semantic memory—that was, after all, the reason you were studying. You probably remember where you were studying, as well as about when you started and when you stopped. You probably also can remember some minor occurrences, such as a burst of loud laughter from the room next door or the coffee you spilled on the desk. Is episodic or semantic memory involved here? Tulving (1983, 2000) argues that semantic and episodic systems often work together in forming new memories. In such cases, the memory that ultimately is formed might consist of an autobiographical episode *and* semantic information.

Implicit (Nondeclarative) Memory In addition to explicit memory, there is a type of long-term memory that is related to nonconsciously remembering skills and sensory perceptions rather than consciously remembering facts. **Implicit memory (nondeclarative memory)** is memory in which behavior is affected by prior experience without a conscious recollection of that experience. Examples of implicit memory include the skills of playing tennis, snowboarding, and typing on a computer keyboard. Another example of implicit memory is the repetition in your mind of a song you heard playing in the supermarket, even though you did not notice that song playing.

Three subsystems of implicit memory are procedural memory, classical conditioning, and priming. All instances of these subsystems consist of memories that you are not aware of, although they predispose you to behave in certain ways (Slotnick & Schacter, 2006).

Procedural memory involves memory for skills. For example (assuming you are an expert typist), as you type a paper, you are not conscious of where the keys are for the various letters, but your well-learned, nonconscious skill of typing allows you to hit the right keys. Once you have learned to drive a car, you remember how to do it: You do not have to remember consciously how to drive the car as you put the key in the ignition, turn the steering wheel, depress the gas pedal, and step on the brake pedal.

To illustrate the distinction between explicit memory and procedural memory, imagine you are at Wimbledon. Serena Williams moves gracefully for a wide forehand, finishes her follow-through, runs quickly back to the center of the court, pushes off for a short ball, and volleys the ball for a winner. If asked about this sequence, she probably would have difficulty explaining each move. In contrast, if we were to ask her who her toughest opponent is, she might quickly respond, "My sister." In the first instance, she would be unable verbally to describe exactly what she had done because her actions had been based on procedural memory. In the second case, she has no problem answering our question because it is based on explicit memory.



Another type of implicit memory involves *classical conditioning*, a form of learning discussed in Chapter 7 (Brignell & Curran, 2006). Recall that classical conditioning involves the automatic learning of associations between stimuli. For instance, an individual who is constantly criticized may develop high blood pressure or other physical problems. Classically conditioned associations such as this involve nonconscious, implicit memory.

A final type of implicit memory process is priming. **Priming** is the activation of information that people already have in storage to help them remember new information better and faster (Geraci, 2006). In a common demonstration of priming, individuals study a list of words (such as *hope, walk,* and *cake*). Then they are given a standard recognition task to assess explicit memory. They must select all of the words that appeared in the list—for example, "Did you see the word *hope*? Did you see the word *form*?" Then participants perform a "stem-completion" task, which assesses implicit memory. In this task, they view a list of incomplete words (for example, *ho__*, *wa_ _*, *ca__*), called word stems, and must fill in the blanks with whatever word comes to mind. The results show that individuals more often fill in the blanks with the previously studied words than would be expected if they were filling in the blanks randomly. For example, they are more likely to complete the stem *ho__* with *hope* than with *hole*. This result occurs even when individuals do not recognize the words on the earlier recognition task. Because priming takes place even when explicit memory for previous information is not required, it is assumed to be an involuntary and nonconscious process (Verfaellie & others, 2006).

In a sense, priming occurs when something in the environment evokes a response in memory—such as the activation of a particular concept or network of meaning. Priming a term or concept makes it more available in memory (Kahan, Sellinger, & Broman-Fulks, 2006; Orfanidou, Marsien-Wilson, & Davis, 2006). John Bargh and other social psychologists have demonstrated that priming can have a surprising influence on social behavior as well (Bargh, 2005, 2006; Chartrand, Maddux, & Lakin, 2005; Pinel & others, 2006; Smith & others, 2006). For example, in one study, college students were asked to unscramble a series of words to make a sentence (Bargh, Chen, & Burrows, 1996). For some of the participants, the items in the series included such words as *rude, aggressively, intrude,* and *bluntly*. For other students, the words included *polite, cautious,* and *sensitively*. Upon completing the scrambled sentences, participants were to report to the experimenter, but each participant encountered the experimenter deep in conversation with another person. Who was more likely to interrupt the ongoing conversation? Among those who were primed with words connoting rudeness, 67 percent interrupted the experimenter. Among those in the "polite" condition, a full 84 percent of the participants waited the entire 10 minutes—never interrupting the ongoing conversation.

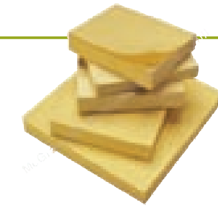
Bargh and his colleagues argue that primes have an automatic impact on behavior, and they call this effect *ideomotoring*—the way that automatic processes impact social behavior outside of awareness (Bargh, 2005, 2006; Ferguson, Bargh, & Nayak, 2005). Priming can also spur goal-directed behavior. For example, Bargh and colleagues (2001) asked students to perform a word-find puzzle. Embedded in the puzzle were either neutral words (*shampoo, robin*) or achievement-related words (*compete, win, achieve*). Participants who were exposed to the achievement-related words did better on a later puzzle task, finding 26 words in other puzzles, while those with the neutral primes found only 21.5. Other

semantic memory A person's knowledge about the world.

implicit memory (nondeclarative memory) Memory in which behavior is affected by prior experience without that experience being consciously recollected.

procedural memory Memory for skills.

priming A type of implicit memory involving the activation of information that people already have in storage to help them remember new information better and faster.



PSYCHOLOGY AND LIFE

Harnessing the Power of Priming

What does the power of priming mean for everyday life? One bit of advice is to be careful how you prime yourself. Look around at your environment. What stands out? What sorts of messages might you be encoding without realizing it?

If nothing else, studies indicate that a few Post-it notes of encouragement, perhaps featuring an inspiring quote or two, might not be a bad idea. Subtle reminders of what makes life worth living, things you enjoy, the people you love, and the reasons you are pursuing your goals may help keep you focused and able to harness the power of positive thinking in your daily life. Surrounding yourself with chronic reminders of your aspirations might just allow you to take advantage of the power of priming!

research has shown that individuals primed with words like *professor* and *intelligent* performed better at a game of Trivial Pursuit than those primed with words like *stupid* and *hooligan* (Dijksterhuis & Van Knippenberg, 1998). Significantly, these effects occur without awareness, with no participants reporting suspicion about the effects of the primes on their behavior. The influence of priming on everyday life is the focus of the Psychology and Life box.

How Memory Is Organized Cognitive psychologists have been successful in classifying the types of long-term memory. But explaining what forms long-term memory does not address the question of how the different types of memory are organized for storage. The word *organized* is important: Memories are not haphazardly stored but instead are carefully sorted.

Here is a demonstration. Recall the 12 months of the year as quickly as you can. How long did it take you? What was the order of your recall? Chances are, you listed them within a few seconds in "natural," chronological order (January, February, March, and so on). Now try to remember the months in alphabetical order. How long did it take you? Did you make any errors? It should be obvious that your memory for the months of the year is organized in a particular way. Indeed, one of memory's most distinctive features is its organization. Researchers have found that, if people are encouraged to organize material simply, their memories of the material improve even if they receive no warning

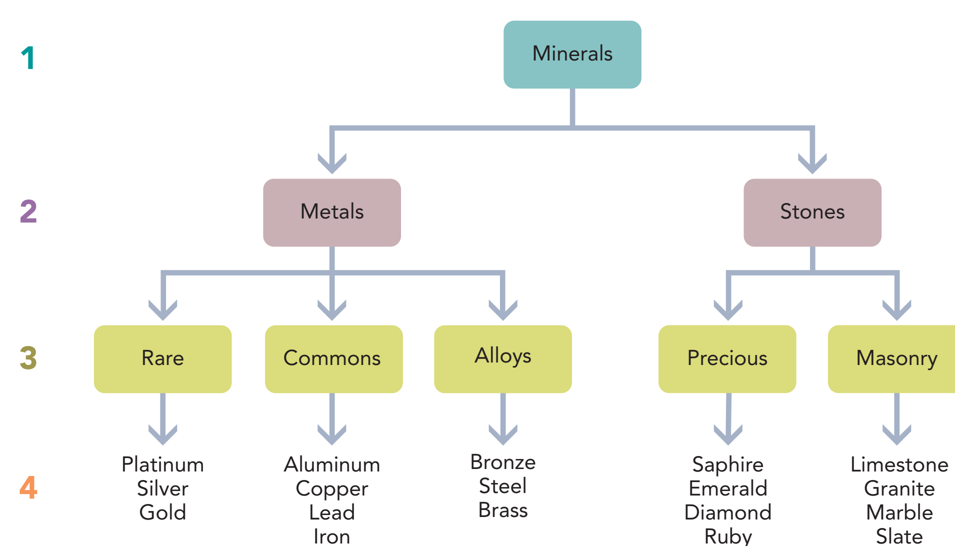


FIGURE 8.11

Example of Hierarchical Organization

A study by Gordon Bower and colleagues (1969) showed that when words are organized hierarchically, as in this example, individuals remember them better than they do when given the words in random groupings.

that their memories will be tested (Mandler, 1980). Psychologists have developed four main theories of how long-term memory is organized: hierarchies, semantic networks, schemas, and connectionist networks.

Hierarchies In many instances, we remember facts better when we organize them hierarchically (Alvarez-Lacalle & others, 2006; Colom & others, 2006). A *hierarchy* is a system in which items are organized from general to specific classes. One common example is the organizational chart showing the relationship of units in a business or a school, with the CEO or president at the top, the vice presidents or deans at the next level, and the managers or professors at a third level. This textbook also is organized hierarchically—with four levels of headings—to help you understand how the various bits of information in the book are related; the table of contents provides a visual representation of the hierarchy of the top two levels of headings.

In an early research study, Gordon Bower and his colleagues (1969) showed the importance of hierarchical organization in memory. Participants who were given words in hierarchies remembered them better than those who were given words in random groupings (Figure 8.11).

Semantic Networks We often use semantic networks to organize material in episodic memory (a form of explicit memory). One of the first network theories claimed that our memories can be envisioned as a complex network of nodes that stand for labels or concepts. The network was assumed to be hierarchically arranged, with more concrete concepts (robin, for example) nested under more abstract concepts (bird).

More recently, cognitive psychologists realized that such hierarchical networks are too simple to describe the way human cognition actually works (Shanks, 1991). For example, people take longer to answer the true-or-false statement "An ostrich is a bird" than they do to answer the statement "A robin is a bird." Memory researchers now see the semantic network as more irregular and distorted: A typical bird, such as a robin, is closer to the node, or center, of the category *bird* than is the atypical ostrich. Figure 8.12 presents an example of the revised model, which allows us to show how typical information is while still illustrating how it is linked together.

We add new material to a semantic network by placing it in the middle of the appropriate region of memory. The new material is gradually tied in to related nodes in the surrounding network. This model reveals why, if you cram for a test, you will not remember the information over the long term. The new material is not woven into the long-term web. In contrast, discussing the material or incorporating it into a research paper interweaves it and connects it to other knowledge you have. These multiple connections increase the probability that you will be able to retrieve the information many months or even years later. The concept of multiple connections fits with the description of the importance of elaboration in memory given earlier in the chapter.

Schemas You and a friend have driven to a new town where neither of you has ever been before. It has been a long drive, and you are tired and hungry. You stop at a local diner, have a seat, and look over the menu. You have never been in this diner before, but you know exactly what is going to happen. Why? Because you have a schema for what happens in a restaurant. When we store information in memory, we often fit it into the collection of information that already exists, as you do even in a new experience with a diner. A **schema** is a preexisting mental concept or framework that helps people to organize and interpret information. Schemas from prior encounters with the environment influence the way we encode, make inferences about, and retrieve information (Morris, 2006).

Semantic network theories assume that memory involves specific facts with clear links from one to another (Passafiume, Di Giacomo, & Carolei, 2006). In contrast, schema theory claims that long-term memory is not very exact. We seldom find precisely the memory that

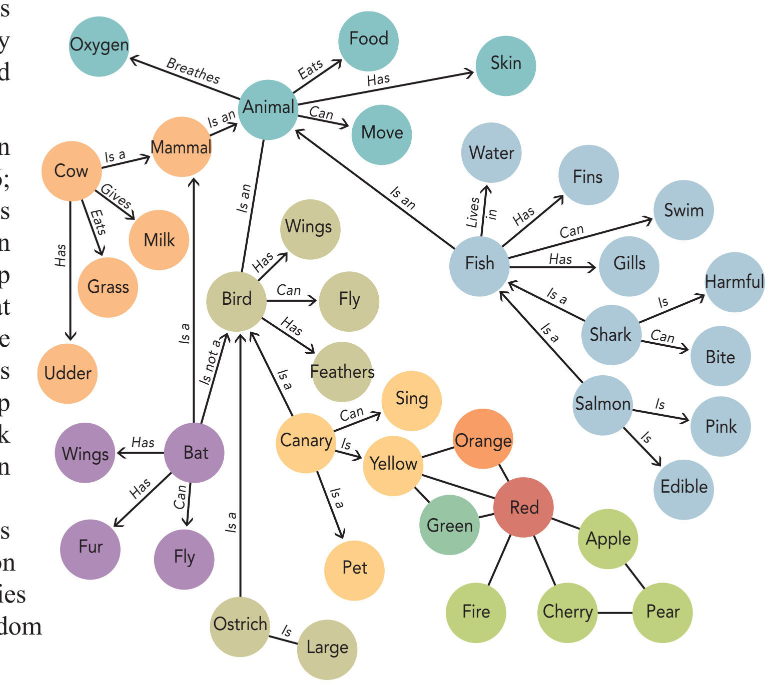


FIGURE 8.12

Revision of the Semantic Network View of Long-Term Memory

In this model, a typical item is closer to the node (center) of its category than an atypical item. Thus the more typical canary is closer to the node bird than the atypical ostrich but farther from the node bird than more typical items such as wings and feathers.

schema A preexisting mental concept or framework that helps people to organize and interpret information.

Shown here are representative scripts from a Japanese tea ceremony, a Western dinner, and an Ethiopian meal. With which script do you feel most comfortable?

we want, or at least not all of what we want; hence, we have to reconstruct the rest. Our schemas support the reconstruction process, helping us fill in gaps between our fragmented memories.

We have schemas for lots of situations and experiences—for scenes and spatial layouts (a beach, a bathroom), as well as for common events (playing football, writing a term paper). A **script** is a schema for an event (Schank & Abelson, 1977). Scripts often have information about physical features, people, and typical occurrences. This kind of information is helpful when people need to figure out what is happening around them. For example, if you are enjoying your after-dinner coffee in an upscale restaurant and a man in a tuxedo comes over and puts a piece of paper on the table, your script tells you that the man probably is a waiter who has just given you the check. Thus scripts help to organize our storage of memories about events.

Connectionist Networks Theories of semantic networks and schemas have little or nothing to say about the role of the physical brain in memory. Thus a new theory based on brain research has generated a wave of excitement among psychologists. **Connectionism,** or **parallel distributed processing (PDP),** is the theory that memory is stored throughout the brain in connections among neurons, several of which may work together to process a single memory (Borowsky & Besner, 2006; Takashima & others, 2006). We initially considered the concept of neural networks in Chapter 3 and the idea of parallel processing pathways in Chapter 5. This section expands on those discussions and applies these concepts to memory.

In the connectionist view, memories are neither abstract concepts (as in semantic network theories) nor large knowledge structures (as in schema theories). Instead, memories are more like electrical impulses, organized only to the extent that neurons, the connections among them, and their activity are organized. Any piece of knowledge—such as your dog's name—is embedded in the strengths of hundreds or thousands of connections among neurons and is not limited to a single location. Figure 8.13 compares the semantic-network, schema, and connectionist-network theories of memories.

How does the connectionist process work? A neural activity involving memory, such as remembering your dog's name, is distributed across a number of areas of the cerebral cortex. The locations of neural activity, called *nodes*, are interconnected. When a node reaches a critical level of activation, it can affect another node, either by exciting it or by inhibiting it, across synapses. We know that the human cerebral cortex contains millions of neurons that are richly interconnected through hundreds of millions of synapses. Because

script A schema for an event.

connectionism (parallel distributed processing [PDP]) The theory that memory is stored throughout the brain in connections between neurons, several of which may work together to process a single memory.

	Theory		
	Semantic Network	Schema	Connectionist
Nature of memory units	Abstract concepts ("bird")	Large knowledge structures ("going to a restaurant")	Small units, connections among neurons
Number of units	Tens of thousands	Unknown	Tens of millions
Formation of new memories	Form new nodes	Form new schemas or modify old ones	Increased strength of excitatory connections among neurons
Attention to brain structure	Little	Little	Extensive

FIGURE 8.13
Key Features of Semantic Network, Schema, and Connectionist Theories
The figure compares the main aspects of three key theories of memory.

of these synaptic connections, the activity of one neuron can be influenced by many other neurons. For example, if an excitatory connection exists between neurons A and B, activity in neuron A will tend to increase activity in neuron B. If the connection is inhibitory, activity in neuron A will tend to reduce the activity in neuron B. Because of these simple reactions, the connectionist view argues that changes in the strength of synaptic connections are the fundamental bases of memory (de Zubicaray, 2006; Maia & Cleeremans, 2005).

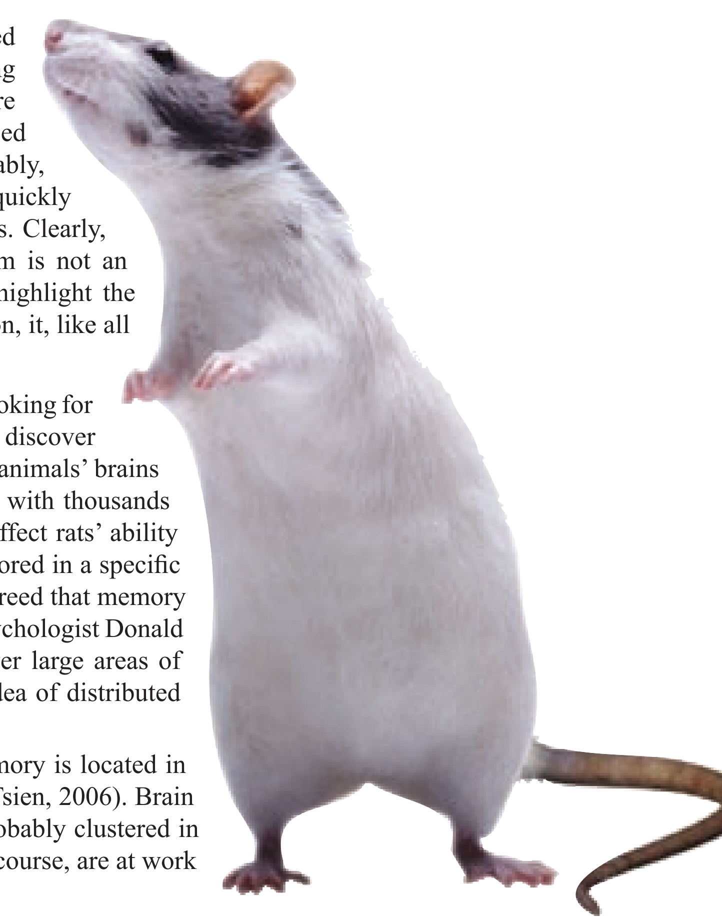
Part of the appeal of the connectionist view is that it is consistent with what we know about brain function. Another part of its appeal is that, when programmed on a computer, the connectionist view has successfully predicted the results of some memory experiments (Marcus, 2001; McClelland & Rumelhart, 1986). Its insights into the organization of memory also support brain research undertaken to determine where memories are stored in the brain (Lin, Osan, & Tsien, 2006; Rogers & Kesner, 2006).

Thus far we have examined the many ways cognitive psychologists think about how information is stored. But the question remains, *where*? Is there a spot in your brain where that special evening with your significant other is waiting for retrieval?

The question of the physical location of memories has long fascinated psychologists. In the 1960s, researchers examined this question using planaria (worms) (Walker & Milton, 1966). In this study, worms first were trained to travel through a maze. Then the trained worms were sacrificed and fed to naive worms—worms that had not been trained. Remarkably, the worms that had eaten the trained worms picked up the maze more quickly than the worms that had not cannibalized their maze-skilled comrades. Clearly, human memory is not the same as worm memory—and cannibalism is not an effective means of gaining information. But this old research does highlight the notion that although memory may seem to be a mysterious phenomenon, it, like all psychological processes, must occur in a physical place: the brain.

Where Memories Are Stored Karl Lashley (1950) spent a lifetime looking for a location in the brain in which memories are stored. He trained rats to discover the correct pathway in a maze and then cut out various portions of the animals' brains and retested their memory of the maze pathway. After experimenting with thousands of rats, Lashley found that the loss of various cortical areas did not affect rats' ability to remember the pathway. Lashley concluded that memories are not stored in a specific location in the brain. Other researchers, continuing Lashley's quest, agreed that memory storage is diffuse, but they developed some other insights. Canadian psychologist Donald Hebb (1949, 1980) suggested that assemblies of cells, distributed over large areas of the cerebral cortex, work together to represent information. Hebb's idea of distributed memory was farsighted.

Neurons and Memory Today many neuroscientists believe that memory is located in specific sets or circuits of neurons (Aleksandrov, 2006; Wang, Hu, & Tsien, 2006). Brain researcher Larry Squire, for example, says that most memories are probably clustered in groups of about 1,000 neurons (1990, 2004, 2007). Single neurons, of course, are at work



INTERSECTION

Memory and Sensation: Why Does Smell Share a Special Relationship with Memory?

You smell a turkey roasting in the oven, and suddenly you are once again 6 years old and eagerly anticipating your family's Thanksgiving dinner. Or the smell of your *abuela's* (grandmother's) tamales reminds you of so many Christmases past. Perhaps less pleasantly, you smell the cologne of a former romantic partner, and your last argument with your "ex" is vividly present to you. Of all of the senses, smell seems to bear the strongest relationship to memory, and a smell can trigger rich emotional memories. Indeed, Marcel Proust described this link so powerfully in his novel *Swann's Way* that the term the *Proust effect* was coined for the ability of smell to transport us into vivid memory.

A smell can trigger rich emotional memories.

Why does smell share such a special relationship with memory? At least part of the answer is anatomical. Recall from Chapter 5 that nerves in the nose send information about smells to the primary olfactory cortex in the brain. That cortex links directly to the amygdala and hippocampus. Thus smells have a superhighway to the brain structures involved in emotion (the amygdala) and memory consolidation (the hippocampus) (Galan & others, 2006; Herz, Schlanker, & Beland, 2004). Rachel Herz (2004) found that autobiographical memories that were cued by odors (a campfire, fresh-cut grass, popcorn) were more emotional and more evocative than such memories cued by pictures or sounds. Indeed, smells can be powerful tools for memory. Herz and Gerald Cupchik (1995; Herz, 1998) found that individuals performed better on a surprise memory test if the same odor cue was present in the room during learning and recall. One implication of that study is that it might be a good idea to wear the same cologne to an exam that you typically wear to class.

But showing that smells indeed influence memory, and that the brain seems to have evolved to give smell a privileged place relative to other sensory input, does not help us understand why the special status of smell is adaptive. Why would it be adaptive to give smell a special link with emotion and memory? Many other animals detect important information about their environments from smell; that is why, for instance, dogs' noses are so close to the ground (and so sensitive). Animals use smells to navigate through the world—to detect what is good (the smell of a food) and what is bad (the scent of a predator). In humans, emotions play a similar role, in that they tell us how we are doing in the world in terms of what matters to us. Perhaps for humans, the special link between smells and emotions allows us quickly to learn associations between particular smells and stimuli that are good (morning coffee) or bad (spoiled milk) for us. As the examples above suggest, smells may have a special power in the positive emotional experience of nostalgia. The right smells alone can transport us powerfully to the good old days.

in memory (Squire, 2007). Researchers who measure the electrical activity of single cells have found that some respond to faces and others to eye or hair color, for example. But in order for you to recognize your Uncle Albert, individual neurons that provide information about hair color, size, and other characteristics act together.

Researchers also believe that brain chemicals may be the ink with which memories are written. Ironically, some of the answers to complex questions about neural mechanics of memory come from studies on a very simple experimental animal—the inelegant sea slug. Eric Kandel and James Schwartz (1982) chose this large snail-without-a-shell because of the simple architecture of its nervous system, which consists of only about 10,000 neurons. (You might recall from Chapter 3 that the human brain has about 100 billion neurons.) The sea slug is hardly a quick learner or an animal with a good memory, but it is equipped

with a reliable reflex. When anything touches the gill on its back, it quickly withdraws it. First the researchers accustomed the sea slug to having its gill prodded. After a while, the animal ignored the prod and stopped withdrawing its gill. Next the researchers applied an electric shock to its tail when they touched the gill. After many rounds of the shock-accompanied prod, the sea slug violently withdrew its gill at the slightest touch. The researchers found that the sea slug remembered this message for hours or even weeks. They also determined that shocking the sea slug's gill releases the neurotransmitter serotonin at the synapses of its nervous system, and this chemical release basically provides a reminder that the gill was shocked. This "memory" informs the nerve cell to send out chemical commands to retract the gill the next time it is touched. If nature builds complexity out of simplicity, then the mechanism used by the sea slug may work in the human brain as well.

Researchers have proposed the concept of *long-term potentiation* to explain how memory functions at the neuron level. In line with connectionist theory, this concept states that, if two neurons are activated at the same time, the connection between them—and thus the memory—may be strengthened (Kavushansky & others, 2006; Lee & Thompson, 2006). Long-term potentiation has been demonstrated experimentally by administering a drug that increases the flow of information from one neuron to another across the synapse (Shakesby, Anwyl, & Rowan, 2002). In one study, rats given the drug learned a maze with far fewer mistakes along the way than those not given the drug (Service, 1994). In another study, the genes of mice were altered to increase long-term potentiation in the hippocampus and other areas of the brain (Tang & others, 1999; Tsien, 2000). The mice with the enhanced genes remembered information better than mice whose genes had not been altered. These studies raise the possibility of someday improving memory through drugs or even gene enhancement to increase neural connections (Schacter, 2001).

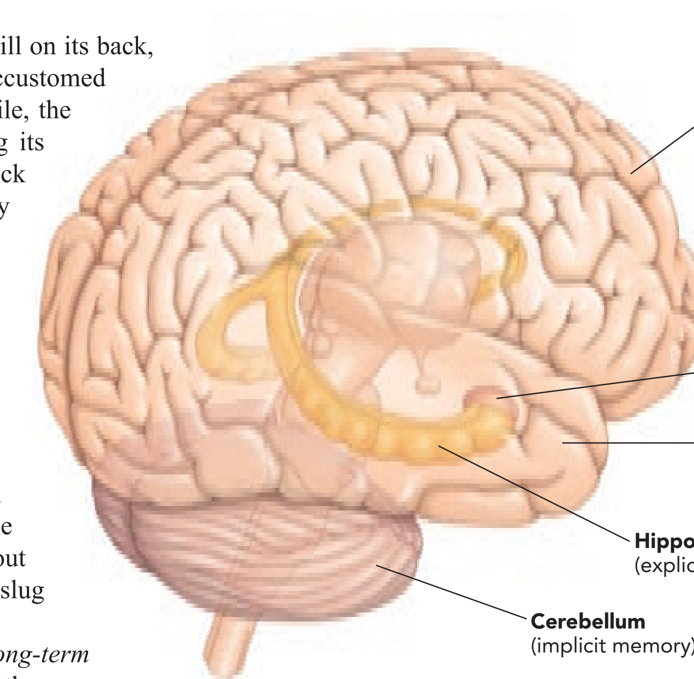


FIGURE 8.14
Structures of the Brain Involved in Different Aspects of Long-Term Memory Note that explicit memory and implicit memory appear to involve different locations in the brain.

Brain Structures and Memory Functions Whereas some neuroscientists are unveiling the cellular basis of memory, others are examining its broad-scale architecture in the brain. Many different parts of the brain and nervous system are involved in the rich, complex process that is memory (Rolls, 2007; Slotnick & Schacter, 2007). Although there is no one "memory" center in the brain, researchers have demonstrated that specific brain structures are involved in particular aspects of memory. For example, the amygdala plays an important role in emotional memories (Doyere & others, 2007; Paz & others, 2006).

Figure 8.14 shows the location of brain structures involved in different types of long-term memory. Note that implicit and explicit memory appear to involve different locations in the brain.

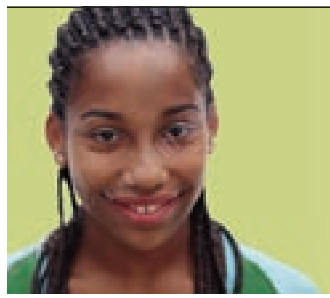
- *Explicit memory:* Neuroscientists have found that the hippocampus, the temporal lobes in the cerebral cortex, and other areas of the limbic system are involved in explicit memory (Lee & Thompson, 2006). In many aspects of explicit memory, information is transmitted from the hippocampus to the frontal lobes, which are involved in both retrospective and prospective memory (McDaniel & Einstein, 2007). The left frontal lobe is especially active when we encode new information into memory; the right frontal lobe is more active when we subsequently retrieve it (Babiloni & others, 2006; Woodward & others, 2006). However, as we saw in Chapter 4, researchers have found that older adults also begin to use the left frontal lobe in retrieval, a development that may be one way older adults compensate for memory problems (Cabeza, 2002; Kramer, Fabiani, & Colcombe, 2006). And as we mentioned earlier, the amygdala, which is part of the limbic system, is involved in emotional memories.

- *Implicit memory:* The cerebellum is involved in the implicit memory required to perform skills (Quintero-Gallego & others, 2006). Various areas of the cerebral cortex, such as the temporal lobes and hippocampus, function in priming (Kristjansson & others, 2006).

Neuroscientists studying memory have benefited greatly from the use of MRI scans, which allow the tracking of neural activity during cognitive tasks (Cabeza & St. Jacques, in press; Raichle & Mintun, 2006). In one research study, participants were shown color photographs of indoor and outdoor scenes while in an MRI machine (Brewer & others, 1998). They were not told that they would be given a memory test about the scenes. After the MRI scans, they were asked which pictures they remembered well, vaguely, or not at all. Their memories were compared with the brain scans. The greater the activation in both prefrontal lobes and a particular region of the hippocampus, the better the participants remembered the scenes. Pictures paired with weak brain activity in these areas were forgotten.

As can be seen in our discussion so far, there is currently extensive interest in studying links between memory and neuroscience. The *Intersection* showcases another example of overlapping fields of psychology, this time involving memory and sensation.

REVIEW AND SHARPEN YOUR THINKING



3 Discuss how memories are stored.

- Explain sensory memory.
- Summarize how short-term memory works.
- Describe how long-term memory functions and the role of the brain in memory storage.

How might semantic-network theory explain why cramming for a test is not a good way to acquire long-term memory?

4 Memory Retrieval

Summarize how memories are retrieved.

Remember that unforgettable night of shining stars with your romantic partner? Let's say the evening has indeed been encoded deeply and elaborately in your memory. Through the years you have thought about the night a great deal and maybe told your best friends about it. The story of that night has become part of the longer story of your life with your significant other. Fifty years later, your grandson asks, "How did you two end up together?" You share that story you have been saving for just such a question. What are the processes that allow you to do so? Memory **retrieval** takes place when information that was retained in memory is taken out of storage. You might think of long-term memory as a library. You retrieve information in a fashion similar to the process you use to locate and check out a book in an actual library. To retrieve something from your mental data bank, you search your store of memory to find the relevant information.

The efficiency with which you retrieve information from memory is impressive. It usually takes only a moment to search through a vast storehouse to find the information you want. When were you born? What was the name of your first date? Who developed the first psychology laboratory? You can, of course, answer these questions instantly. Yet retrieval of memory is a complex and sometimes imperfect process (Dodd, Castel, & Roberts, 2006; Spear, 2007).

Before examining ways that retrieval may fall short, let's turn to some basic concepts and variables that are known to affect the likelihood that information will be accurately encoded, stored, and ultimately retrieved. As we will see, retrieval is very much dependent on the circumstances under which a memory was encoded and the way it was retained (Gardiner, 2007; Radvansky, 2006).

Serial Position Effect

The **serial position effect** is the tendency to recall more readily the items at the beginning and end of a list. If you are a fan of reality TV, you might notice that you always seem to remember the first person to get "voted off" and the last few survivors. But all those people in the middle are just a blur. The *primacy effect* refers to better recall for items at the beginning of a list. The *recency effect* refers to better recall for items at the end of the list. Together with the relatively low recall of items from the middle of the list, this pattern makes up the *serial position effect* (Surprenant, 2001). See Figure 8.15 for a typical serial position effect that shows a weaker primacy effect and a stronger recency effect. One application of primacy and recency effects is the advice to job candidates to try to be the first or last candidate interviewed.

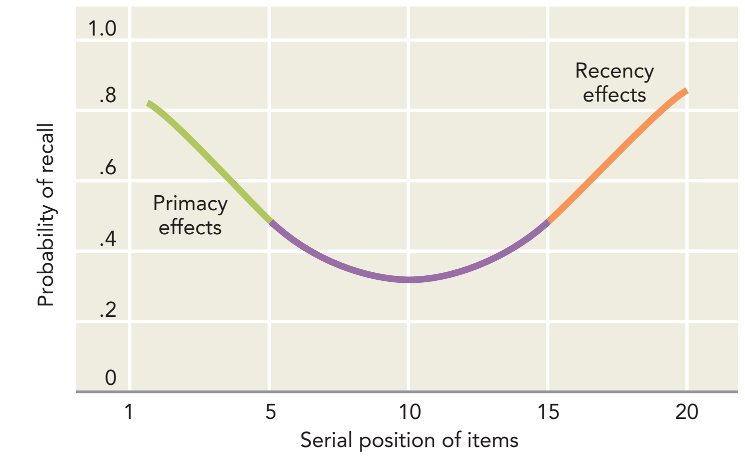


FIGURE 8.15

The Serial Position Effect When a person is asked to memorize a list of words, the words memorized last usually are recalled best, those at the beginning next best, and those in the middle least efficiently.

These effects are explained using principles of encoding that we have already examined. With respect to the primacy effect, the first few items in the list are easily remembered because they are rehearsed more or because they receive more elaborative processing than do words later in the list (Atkinson & Shiffrin, 1968; Craik & Tulving, 1975). Working memory is relatively empty when the items enter, so there is little competition for rehearsal time. And because the items get more rehearsal, they stay in working memory longer and are more likely to be encoded successfully into long-term memory. In contrast, many items from the middle of the list drop out of working memory before being encoded into long-term memory.

As for the recency effect, the last several items are remembered for different reasons. First, when these items are recalled, they might still be in working memory. Second, even if these items are not in working memory, their recency compared with other list items makes them easier to recall. For example, if you are a sports fan, try remembering a game you saw at the end of the season. You probably will find that more recent games are easier to remember than earlier games.

Retrieval Cues and the Retrieval Task

Two other factors involved in retrieval are (1) the nature of the cues that can prompt your memory and (2) the retrieval task that you set for yourself. If effective cues for what you are trying to remember do not seem to be available, you need to create them—a process that takes place in working memory (Carpenter & DeLosh, 2006). For example, if you have a block about remembering a new friend's name, you might go through the alphabet, generating names that begin with each letter. If you manage to stumble across the right name, you will probably recognize it.

We can learn to generate retrieval cues (Allan & others, 2001). One good strategy is to use different subcategories as retrieval cues. For example, write down the names of as many of your classmates from middle or junior high school as you can remember. When you run out of names, think about the activities you were involved in during those school years, such as math class, student council, lunch, drill team, and so on. Did this set of cues help you to remember more of your classmates?

Although cues help, your success in retrieving information also depends on the task you set for yourself. For instance, if you are simply trying to decide if something seems familiar, retrieval is probably a snap. Let's say you see a short, dark-haired woman walking toward you. You quickly decide she is someone who lives in the next dorm or shops at the same supermarket as you do. But remembering her name or a precise detail, such as when you met her, can be harder. Such distinctions have implications for police investigations: A witness might be certain she has previously seen a face, yet she might have a hard time deciding if it was at the scene of the crime or in a mug shot.

retrieval The memory process of taking information out of storage.

serial position effect The tendency for items at the beginning and at the end of a list to be recalled more readily.

Recall and Recognition The presence or absence of good cues and the retrieval task required are factors in an important memory distinction: recall versus recognition (Nobel & Shiffrin, 2001). *Recall* is a memory task in which the individual has to retrieve previously learned information, as on essay tests. *Recognition* is a memory task in which the individual only has to identify (recognize) learned items, as on multiple-choice tests. Recall tests such as essay tests have poor retrieval cues. You are told to try to recall a certain class of information ("Discuss the factors that caused World War II"). In recognition tests such as multiple-choice tests, you merely judge whether a stimulus is familiar (whether it matches something you experienced in the past).

You probably have heard some people say that they are terrible at remembering names but that they never forget a face. What they likely are really saying is that they are better at recognition (realizing that they have seen a face before) than at recall (remembering a person's name in response to his or her face). If you have made that claim yourself, try to recall an actual face. It is not easy, as law enforcement officers know. In some cases, they bring in an artist to draw the suspect's face from witnesses' descriptions (Figure 8.16). But recalling faces is difficult, and artists' sketches of suspects are frequently not detailed or accurate enough to result in apprehension.

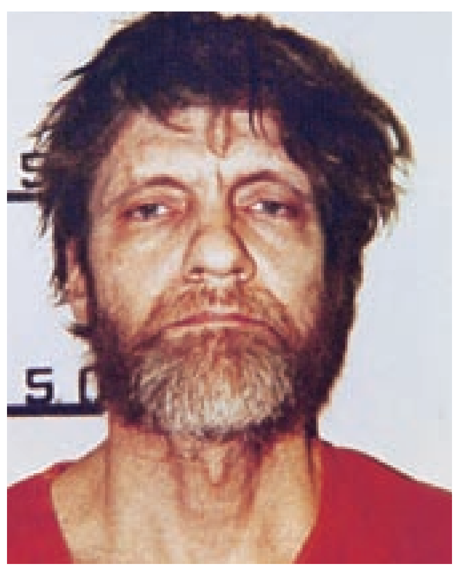


FIGURE 8.16

Remembering Faces *(Top)* The FBI artist's sketch of Ted Kaczynski. Kaczynski, also known as the Unabomber, is a serial killer who conducted a sequence of mail bombings targeting universities and airlines beginning in the late 1970s. *(Bottom)* A photograph of Kaczynski. The FBI widely circulated the artist's sketch, which was based on bits and pieces of observations people had made of the infamous Unabomber, in the hope that someone would recognize him. Would you have been able to recognize Kaczynski from the artist's sketch? Probably not. Although most people say they are good at remembering faces, they usually are not as good as they think they are.

Encoding Specificity Another consideration in understanding retrieval is the *encoding specificity principle*, which states that information present at the time of encoding or learning tends to be effective as a retrieval cue (Hannon & Craik, 2001; Zeelenberg, 2005). For example, you know your instructors in your classes—you see them all the time in class. But coming upon one of them in an unexpected setting (say, at a bar or in a doctor's office) or in more casual clothes, you might find the person's name escapes you. Memory might fail because the cues you encoded are not available for use. Encoding specificity is compatible with our earlier discussion of elaboration. Recall that the more elaboration you use in encoding information, the better your memory of the information will be. Encoding specificity and elaboration reveal how interdependent encoding and retrieval are.

Context and State at Encoding and Retrieval An important consequence of encoding specificity is that a change in context between encoding and retrieval can cause memory to fail (Fanselow, 2007; Smith, 2007). In many instances, people remember better when they attempt to recall information in the same context in which they learned it—a process referred to as *context-dependent memory*. This better recollection is believed to occur because they have encoded features of the context in which they learned the information along with the actual information. Such features can later act as retrieval cues (Dobbins & Han, 2006; Eich, 2007).

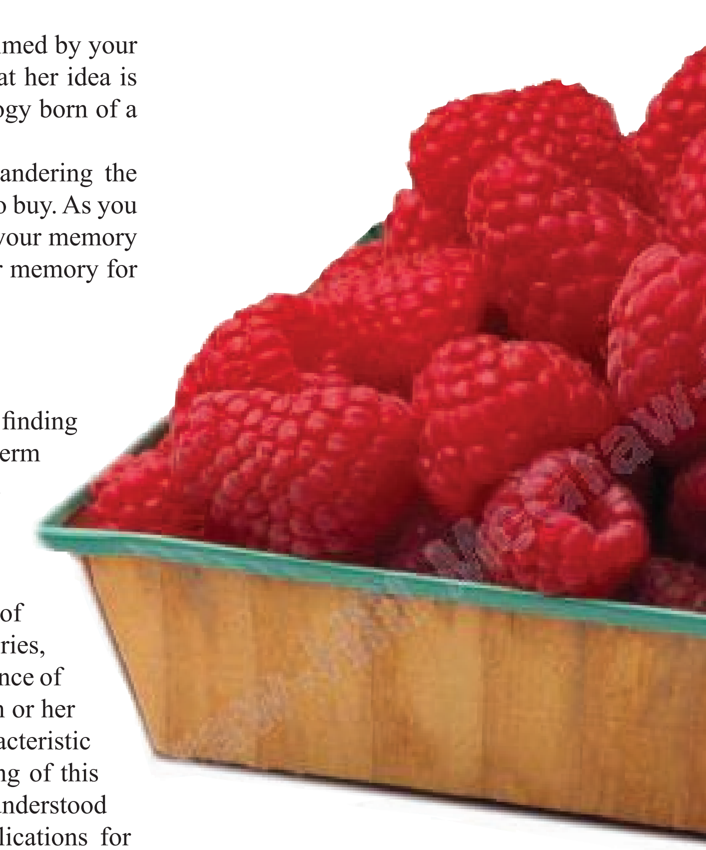
In one study, scuba divers learned information on land and under water (Godden & Baddeley, 1975). Later they were asked to recall the information when they either were on land or under water. The divers' recall was much better when the encoding and retrieval contexts were the same (both on land or both under water).

Just as external contexts can influence memory, so can internal states (Duka, Weissenborn, & Dienes, 2001; Weissenborn & Duka, 2000). People tend to remember information better when their psychological state or mood is similar at encoding and retrieval, a process referred to as *state-dependent memory*. For example, when people are in sad moods, they are more likely to remember negative experiences such as failure and rejection. When they are in happy moods, they are inclined to remember positive experiences such as success and acceptance (Mineka & Nugent, 1995). Unfortunately, when individuals who are depressed recall negative experiences, it tends to perpetuate their depression (Nolen-Hoeksema, 2007).

Priming Retrieval also benefits from *priming*. Recall that priming means that people remember information better and faster when it is preceded by similar information. Priming is a form of implicit memory that is nonconscious (Goddard, Dritschel, & Burton, 2001).

Priming is likely involved in unintentional acts of plagiarism (Schacter, 1996). For example, let's say you propose an idea to a friend, who seems unimpressed by it or even rejects it outright. Weeks or months later, the friend excitedly describes your idea as if she had just come up with it herself. Her memory of having the idea has been primed by your explanation of the idea. When you call your friend's attention to the fact that her idea is really your idea, you likely will face either heated denial or a sheepish apology born of a sudden dose of explicit memory.

A practical example of priming involves those times when you are wandering the supermarket aisles, unable to remember one of the items you were supposed to buy. As you walk, you hear two people talking about fruit, and the conversation triggers your memory that you were supposed to buy raspberries. That is, hearing *fruit* primes your memory for raspberries.



Special Cases of Retrieval

We began this discussion by likening the retrieval process to looking for and finding a book in the library. But the process of retrieving information from long-term memory is not as precise as the library analogy suggests. When we search through our long-term memory storehouse, we do not always find the exact "book" we want. Or we might find the book we want but discover that several pages are missing. We have to fill in these gaps somehow.

Our memories are affected by a number of things, including the pattern of facts we remember, schemas and scripts, the situations we associate with memories, and the personal or emotional context. Certainly, everyone has had the experience of remembering a shared situation with a particular individual, only to have him or her remind us, "Oh, that wasn't *me*!" Such moments (allegedly a common characteristic of James Frey's controversial "memoir" that was mentioned at the beginning of this chapter) have provided convincing evidence that memory may well be best understood as "reconstructive." This subjective quality of memory certainly has implications for important day-to-day procedures such as eyewitness testimony (Greene, 1999).

While the factors that we have discussed so far relate to the retrieval of generic information, various kinds of special memory retrieval also have generated a great deal of research. These memories have special significance because of their relevance to the self, to their emotional or traumatic character, or because they show unusually high levels of apparent accuracy (Piolino & others, 2006). We now turn to these special cases of memory. Researchers in cognitive psychology have debated whether these memories rely on processes that are different from those already described or are simply extreme cases of typical memory processes (Lane & Schooler, 2004; Schooler & Eich, 2000).

Retrieval of Autobiographical Memories *Autobiographical memory,* a special form of episodic memory, is a person's recollections of his or her life experiences (Cabeza & St. Jacques, in press; Knez, 2006). Autobiographical memories are complex and seem to contain unending strings of stories and snapshots, but researchers have found that they can be categorized (Roediger & Marsh, 2003). For example, based on their research, Martin Conway and David Rubin (1993) sketched a structure of autobiographical memory that has three levels (Figure 8.17). The most abstract level consists of *life time periods;* for example, you might remember something about your life in high school. The middle level in the hierarchy is made up of *general events*, such as a trip you took with your friends after you graduated from high school. The most concrete level in the hierarchy is composed of *event-specific knowledge;* for example, from your postgraduation trip, you might remember the exhilarating time you had the very first time you jet-skied. When people tell their life stories, all three levels of information are usually present and intertwined.

Most autobiographical memories include some reality and some myth. Personality psychologist Dan McAdams argues that autobiographical memories are in fact less about facts and more about meanings (2001, 2006; McAdams & others, 2006). They provide a reconstructed, embellished telling of the past that connects the past to the present. According to McAdams, autobiographical memories form the core of our personal identity. A number of studies have now shown that the stories we tell about our lives have important implications (Kroger, 2007). For instance, McAdams and his colleagues have

FIGURE 8.17

The Three-Level Hierarchical Structure of Autobiographical Memory When people relate their life stories, all three levels of information are typically present and intertwined.

Level	Label	Description
Level 1	Life time periods	Long segments of time measured in years and even decades
Level 2	General events	Extended composite episodes measured in days, weeks, or months
Level 3	Event-specific knowledge	Individual episodes measured in seconds, minutes or hours

demonstrated that individuals who describe important life experiences that go from bad to better (redemptive stories) are more generative—that is, they are the kind of people who make a contribution to future generations, people who leave a legacy that will outlive them (Bauer, McAdams, & Sakaeda, 2005). These individuals are also better adjusted than those whose self-defining memories go from good to bad (labeled *contamination stories*).

Similar results have come from research on parents of children with Down syndrome. Parents whose autobiographical memories ended happily when recalling the experience of finding out about their child's diagnosis scored higher on measures of happiness, life meaning, and personal growth (King & others, 2000). Similarly, research on the coming-out stories of gay men and lesbians has shown that individuals whose autobiographical memory includes warm acceptance and the experience of falling in love are likely to score higher on measures of psychological well-being as well as personality development (King & Smith, 2005). Clearly, the construction and reconstruction of autobiographical memory may reveal important aspects of how individuals function, grow, and discover meaning in their lives (Crawley & Eacott, 2006; King & Hicks, 2006).

Retrieval of Emotional Memories When we remember our life experiences, the memories are often wrapped in emotion. Emotion affects the encoding and storage of memories and thus shapes the details that are retrieved. The role that emotion plays in memory is of considerable interest to contemporary researchers and has echoes in public life.

Many people have a flashback memory of where they were and what they were doing when terrorists attacked the World Trade Center towers in New York City on September 11, 2001.

Flashbulb memories are memories of emotionally significant events that people often recall with more accuracy and vivid imagery than everyday events (Curci & Luminet, 2006; Davidson, Cook, & Glisky, 2006). Perhaps you can remember where you were when you first heard of the terrorist attacks on the United States on September 11, 2001. An intriguing dimension of flashbulb memories is that several decades later, people often remember where they were and what was going on in their lives at the time of such an emotionally charged event. These memories seem to be part of an adaptive system that fixes in memory the details that accompany important events so that they can be interpreted at a later time.

The vast majority of flashbulb memories are of a personal nature rather than of nationally prominent events or circumstances. In one study, college students were asked to report the three most vivid memories in their lives (Rubin & Kozin, 1984). Virtually all of these memories were of a personal nature. They tended to center on an injury or accident, sports, members of the opposite sex, animals, deaths, the first week of college, and vacations. Students also answered questions about the kinds of events that were most likely to produce flashbulb memories. Figure 8.18 shows which types of events more than 50 percent of the students said were of flashbulb quality.

Event	Percent
A car accident you were in or witnessed	85
When you first met your first college roommate	82
The night of your high school graduation	81
The night of your senior prom (if you went or not)	78
An early romantic experience	77
A time you had to speak in front of an audience	72
When you got your admissions letter	65
Your first date—the moment you met him/her	57

FIGURE 8.18

College Students' Flashbulb Memories The numbers refer to the percent of college students who said these events triggered memories of flashbulb quality.

Most people express confidence about the accuracy of their flashbulb memories. However, most flashbulb memories probably are not as accurately etched in our brains as we think. One way to examine the accuracy of flashbulb memories is to examine how consistent the details of these memories remain over time. For instance, one study examined memories for the details of the attempted assassination of President Ronald Reagan (Pillemer, 1984). About 80 percent of the details that were remembered 1 month after the shooting were also remembered 7 months later. Other research has shown lower consistency over time; for example, one study found that 25 percent of participants included contradictory information in their memories of the *Challenger* space shuttle disaster (Neisser & Harsch, 1992).

Still, on the whole, flashbulb memories do seem more durable and accurate than memories of day-to-day happenings (Davidson, Cook, & Glisky, 2006). One reason that flashbulb memories might tend to be well preserved in memory is that they are quite likely to be rehearsed in the days following the event. However, it is not just the discussion and rehearsal of information that make flashbulb memories so long-lasting. The emotions triggered by flashbulb events also are involved in their durability. The emotional arousal you experienced when you heard about the terrorist attacks also likely contributed to the vividness of your memory.

Although we have focused on negative news events as typical of flashbulb memories, such memories can also occur for positive events. An individual's wedding day and the birth of a child are events that may become milestones in personal history and are always remembered.

Memory for Traumatic Events In 1890, the American psychologist and philosopher William James said that an experience can be so arousing emotionally as to almost leave a scar on the brain's tissue. Personal traumas are candidates for the type of emotionally arousing experience to which James was referring.

Some psychologists argue that memories of emotionally traumatic events are accurately retained, possibly forever, in considerable detail (Langer, 1991). There is good evidence that memory for traumatic events is usually more accurate than memory for ordinary events (Berntsen & Rubin, 2006; Schooler & Eich, 2000). Consider the traumatic experience of the children who were kidnapped at gunpoint on a school bus in Chowchilla, California, in 1983 and then buried underground for 16 hours before escaping. The children had the classic signs of traumatic memory: detailed and vivid recollections.

For rescuers as well as victims in natural and other disasters, memories are typically longer-lasting and more accurate than are recollections of ordinary events. Here Coast Guard Petty Officer 2nd Class Shawn Beaty of Long Island, New York, looks for survivors in the wake of Hurricane Katrina in New Orleans in August 2005.

However, when a child psychiatrist interviewed the children 4 to 5 years after the chilling episode, she noted striking errors and distortions in the memories of half of them (Terr, 1988). How can a traumatic memory be so vivid and detailed, yet at the same time have inaccuracies? A number of factors can be involved. Some children might have made perceptual errors while encoding information because the episode was so shocking. Others might have distorted the information and recalled the episode as being less traumatic than it actually was in order to reduce their anxiety about it. Other children, in discussing the traumatic event with others, might have incorporated bits and pieces of these people's recollections of what happened into their own version of the event.

Usually, memories of real-life traumas are more accurate and longer-lasting than memories of everyday events. Although memories of traumas are subject to deterioration and distortion, the central part of the memory is almost always effectively remembered. Where distortion often arises is in the details of the traumatic episode. Stress-related hormones likely play a role in memories that involve personal trauma. The release of stress-related hormones, signaled by the amygdala (see Figure 8.14), likely accounts for some of the extraordinary durability and vividness of traumatic memories (Bucherelli & others, 2006).

Repressed Memories To say that traumatic events are likely to be remembered hardly seems controversial. But a great deal more debate surrounds the question of whether such memories can be *forgotten and then recovered* (McNally, 2005). *Repression* refers to a defense mechanism by which a person is so traumatized by an event that he or she forgets it and then forgets the act of forgetting. According to psychodynamic theory, which we considered in Chapter 1, repression's main function is to protect the individual from threatening information. Repression does not erase a memory, but it makes conscious remembering extremely difficult (Anderson & Green, 2001).

Just how extensively repression occurs is a controversial issue. Most studies of traumatic memory indicate that a traumatic life event such as childhood sexual abuse is very likely to be remembered. However, there is at least some evidence that childhood sexual abuse may not be remembered. Linda Williams and her colleagues have conducted a number of investigations of memories of childhood abuse (Liang, Williams, & Siegel, 2006; Williams, 2003, 2004). One study involved 129 women for whom hospital records indicated an abuse experience (Williams, 1995). Seventeen years after the abuse incident, the women were contacted and asked (among other things) if they had ever been the victim of childhood sexual abuse. Of the 129 women, 80 reported remembering and never having forgotten the experience. Ten percent of the participants reported having forgotten about the abuse at least for some portion of their lives. Those who reported "recovering" these memories were younger at the time of the incident and were much less likely to have received support from their mothers after the abuse.

If it does exist, repression can be considered a special case of **motivated forgetting,** which occurs when individuals forget something because it is so painful or anxiety-laden that remembering is intolerable (Anderson & others, 2004; Joormann & others, 2005). This type of forgetting may be a consequence of the emotional blows of personal trauma that occur in the experiences of victims of rape or physical abuse, war veterans, or survivors of earthquakes, plane crashes, and other terrifying events. These emotional traumas may haunt people for many years unless they can put the details out of mind. Even when people have not experienced trauma, they may use motivated forgetting to protect themselves from memories of painful, stressful, or otherwise unpleasant circumstances.

Can so-called recovered memories be considered authentic? See the Critical Controversy feature to explore this intriguing question further.

motivated forgetting An act of forgetting something because it is so painful or anxiety-laden that remembering it is intolerable.

Eyewitness Testimony By now, you should realize that memory is not a perfect reflection of reality. Understanding the distortions of memory is especially important when people are called on to report what they saw or heard in relation to a crime. Eyewitness testimonies, like other sorts of memories, may contain errors (Bruck, Ceci, & Principe, 2006; Wright & Loftus, 2007). But faulty memory in criminal matters has especially serious consequences.

When eyewitness testimony is inaccurate, the wrong person may go to jail or even be put to death, or the person who committed the crime might not be prosecuted. Estimates are that between 2,000 and 10,000 people are wrongfully convicted each year in the United States because of faulty eyewitness testimony (Cutler & Penrod, 1995). It is important to note that often witnessing a crime is a traumatic event for the individual, and so this type of memory typically fits in the larger category of memory for highly emotional events.

Much of the interest in eyewitness testimony focuses on distortion, bias, and inaccuracy in memory (Garry & Loftus, 2007; Loftus, 2006). One reason for distortion is that memory fades. In one study, people were able to identify pictures with 100 percent accuracy after a 2-hour time lapse. However, 4 months later they achieved an accuracy of only 57 percent; chance alone accounts for 50 percent accuracy (Shepard, 1967).

Unlike a videotape, memory can be altered by new information (Dysart & Lindsay, 2007). In one study, students were shown a film of an automobile accident and were asked how fast the white sports car was going when it passed a barn (Loftus, 1975). In fact, there was no barn in the film. However, 17 percent of the students who were asked the question mentioned the barn in their answer.

Bias is also a factor in faulty memory (Brigham & others, 2007). Studies have shown that people of one ethnic group are less likely to recognize individual differences among people of another ethnic group (Behrman & Davey, 2001). Latino eyewitnesses, for example, may have trouble distinguishing among several Asian suspects. In one experiment, a mugging was shown on a television news program (Loftus, 1993). Immediately after, a lineup of six suspects was broadcast, and viewers were asked to phone in and identify which one of the six individuals they thought committed the robbery. Of the 2,000 callers, more than 1,800 identified the wrong person. In addition, even though the robber was White, one-third of the viewers identified an African American or a Latino suspect as the criminal.

Hundreds of individuals have been harmed by witnesses who have made a mistake that they could have avoided (Loftus, 2006; Wright & Loftus, 2007). One estimate indicates that each year, approximately 7,500 people are arrested for and wrongly convicted of serious crimes in the United States (Huff, 2002). Faulty memory is not just about accusing the wrong person. For example, faulty memories were evident in descriptions of the suspects' vehicle in the sniper attacks that killed 10 people in the Washington, D.C., area in 2002. Witnesses reported seeing a white truck or van fleeing several of the crime scenes. It appears that the white van may have been near one of the first shootings and that media repetition of this information contaminated the memories of witnesses to later attacks, making them more likely to remember the white trucks. When caught, the sniper suspects were driving a blue car.

Before police even arrive at a crime scene, witnesses talk among themselves, and this dialogue can contaminate memories. In one situation, Elizabeth Loftus

Faulty memories complicated the search for the perpetrators in the sniper attacks that killed 10 people in the Washington, D.C., area in 2002. Police released photos of the type of white truck or van that witnesses said they saw fleeing some of the crime scenes (right). *In the end, however, the suspects were driving a blue car when law enforcement officials apprehended them* (above).

Critical Controversy

Memories: Recovered, Discovered, or False?

George Franklin, a California man, spent 6 years in prison for the 1969 murder of a young woman. His own daughter's testimony, based on her memory of the crime, was at the heart of the prosecution's case against him. What made this case unusual is that the daughter's memories were allegedly recovered in adulthood as a part of her own ongoing therapy (Loftus & Ketcham, 1991). In fact, Franklin became the first person in the United States to be convicted on the basis of repressed memory evidence. During the 1990s, memories allegedly recovered during therapy also served as the basis for many charges of physical and sexual abuse in various cases. George Franklin's conviction was eventually overturned when it came out that his daughter might have lied about having been hypnotized before the trial.

The idea that childhood abuse—and, in particular, sexual abuse—can be completely repressed yet nevertheless lead to psychological disorders in adulthood was first expressed by Sigmund Freud (1917). Some therapists today continue to believe that adult disorders such as depression, thoughts of suicide, eating disorders, low self-esteem, sexual dysfunction, and trouble maintaining relationships may stem from sexual abuse in childhood. Treatment usually involves bringing these long-repressed childhood traumas back into consciousness, thus freeing the client from their unconscious effects.

Almost all accused parents vehemently deny having ever abused their offspring in childhood. In 1992, the False Memory Syndrome (FMS) Foundation was formed as a parents' support group. An extraordinary aspect of this organization is that its founders are the parents of a woman who is a cognitive psychologist and whose interest in repressed memory is both professional and personal (Freyd, 1996).

It was against this bitter backdrop that experimental psychology entered the fray. Led by the research of memory expert Elizabeth Loftus, study after study found that it is easy to create false memories, especially by using hypnosis (Loftus, 2005, 2006, 2007; Clark & Loftus, 2006; Garry & Loftus, 2007; Wright & Loftus, 2007). All that is required is to hypnotize someone and to suggest that he or she has had an experience. After hypnosis, that person may well "remember" the experience as vividly real. In one study, Loftus and Jacquie Pickrell (2001) persuaded people that they had met Bugs Bunny at Disneyland, even though Bugs is a Warner Bros. character that would never appear at a Disney theme park. The research procedure was quite simple. Four groups of participants read ads and then answered questionnaires about a trip to Disneyland. One group saw an ad that mentioned no cartoon characters, the second read the same ad and saw a 4-foot-tall cardboard figure of Bugs Bunny, the third read a fake ad for Disneyland with Bugs Bunny in it, and the fourth saw the same fake ad along with the cardboard bunny. Although less than 10 percent of the first two groups later reported having actually met Bugs Bunny on a trip to Disneyland, approximately 30 to 40 percent of the third and fourth groups reported remembering meeting Bugs at Disneyland.

Such research added to growing skepticism. There is no question that individuals can "remember," in extraordinary detail, events that are quite unlikely (for example, satanic ritual abuses and alien abductions—indeed, there has never been a proven case of satanic ritual abuse in the United States). Certainly therapeutic techniques such as visualization and hypnosis are prone to contribute to false memories (Schooler & Eich, 2000). Are so-called recovered memories ever authentic? Cognitive psychologist Jonathan Schooler (2002) has suggested that such memories are better termed "discovered" memories, because whether they are accurate or not, individuals certainly experience them as real. Schooler and his colleagues (1997) investigated a number of cases of discovered memories of abuse, in which they sought independent corroboration by others. They were able to identify cases in which a discovered memory could be verified by the perpetrator or some third party. Indeed, such cases do exist. For example, Frank Fitzpatrick's memory of previously "forgotten" abuse at the hands of a Catholic priest was corroborated by witnesses who had also been abused (*Commonwealth of Massachusetts v. Porter,* 1993). Schooler and colleagues found that, in cases of authentic discovered memories, the circumstances leading to the recollection of the memory were similar to the original abuse (for example, hearing about someone else being abused or seeing a movie about it) and did not include therapeutic interventions.

Thus, although some cases of recovered memories clearly have led to unjust treatment (as for George Franklin), it is inappropriate to reject all claims by adults that they were victims of childhood sexual abuse. Current consensus is well represented by the American Psychological Association's (1995) interim report of a working group investigating memories of childhood abuse, which offers these tentative conclusions: (1) Controversies regarding adult recollections should not be allowed to obscure the fact that child sexual abuse is a complex and pervasive problem in the United States that has historically gone unacknowledged; (2) most people who were sexually abused as children remember all or part of what happened to them; (3) it is possible for memories of abuse that have been forgotten for a long time to be remembered, although the mechanism by which such delayed recall occurs is not currently well understood; (4) it is also possible to construct convincing false memories for events that never occurred, although the mechanism by which these false memories occur is not currently well understood; (5) there are gaps in our knowledge about the processes that lead to accurate and inaccurate recollections of childhood abuse.

What Do You Think?

- How should courts of law deal with "discovered memories"?
- Suppose you meet someone who reports a recovered memory of childhood abuse. How can you tell whether that memory should be believed? How might the individual's revelation change your attitude about him or her?
- How does our perspective on discovered memories affect our view of childhood abuse in general? If we cannot trust the testimony of adult survivors of abuse, how can we determine the frequency of childhood abuse today?

(2003) personally witnessed this effect when she entered a shop moments after a robbery had taken place and before police had arrived. In the immediate aftermath, customers and employees shared their memories, in the process influencing others' thoughts. This is why, during the Washington, D.C., sniper attacks in 2002, law enforcement officials advised any persons who might witness the next attack immediately to write down what they had seen—even on their hands if they did not have a piece of paper.

REVIEW AND SHARPEN YOUR THINKING

4 Summarize how memories are retrieved.

- Describe the serial position effect.
- Explain the role of retrieval cues and the retrieval task.
- Discuss the following special cases of retrieval: autobiographical memory, emotional memory, memory of traumatic events, repressed memory, and eyewitness testimony.

Do you think that, on the whole, negative emotional events are likely to be more memorable than positive ones? How would you go about studying whether negative events are more memorable than positive ones?

5 Forgetting

Describe how the failure of encoding and retrieval are involved in forgetting.

Human memory also has its imperfections, as we have all experienced. It is not unusual for two people to argue about whether something did or did not happen, each supremely confident that his memory is accurate and the other person's is faulty. And we all have had the frustrating experience of trying to remember the name of some person or some place but not quite being able to retrieve it.

Imperfections of memory are also in evidence in the stunning, high-profile disagreements that erupt in our nation's legal and political arenas. The trials of Michael Jackson and others show how common it is in a court case for one person to remember events one way and for someone else to recall them differently. Those who played a significant role in highly publicized events such as the search-and-recovery efforts after 9/11, the run-up to the war in Iraq, and the delivery of emergency aid to the victims of Hurricane Katrina often paint different pictures of what happened from their memories. Missed appointments, misplaced eyeglasses, the failure to recall the name of a familiar face, and inability to recall your password for Internet access are everyday examples of forgetting. Why do we forget?

One of psychology's pioneers, Hermann Ebbinghaus (1850–1909), was the first person to conduct scientific research on forgetting. In 1885, he made up and memorized a list of 13 nonsense syllables and then assessed how many of them he could remember as time passed. (*Nonsense syllables* are meaningless combinations of letters that are unlikely to have been learned already, such as *zeq, xid, lek, vut,* and *riy*.) Even just an hour later, Ebbinghaus could recall only a few of the nonsense syllables he had memorized. Figure 8.19 shows Ebbinghaus's learning curve for nonsense syllables. Based on his research, Ebbinghaus concluded that the most forgetting takes place soon after we learn something.

If we forget so quickly, why put effort into learning something? Fortunately, researchers have demonstrated that forgetting is not as extensive as Ebbinghaus envisioned (Jarrold & Towse, 2006). Ebbinghaus studied meaningless nonsense syllables. When we memorize more meaningful material—such as poetry, history, or the content of this text—forgetting is neither so rapid nor so extensive. Following are some of the factors that influence how well we can retrieve information from long-term memory.

Hermann Ebbinghaus (1850–1909)
Ebbinghaus was the first psychologist to conduct scientific research on forgetting.

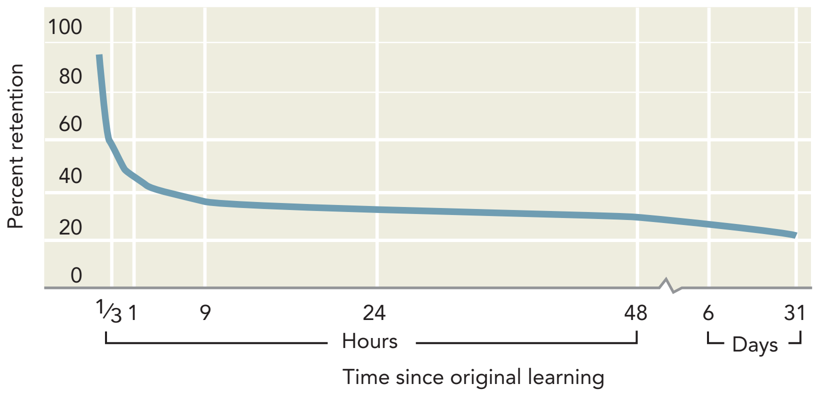


FIGURE 8.19
Ebbinghaus's Forgetting Curve The figure illustrates Ebbinghaus's conclusion that most forgetting occurs soon after we learn something.

Encoding Failure

Sometimes when people say they have forgotten something, they have not really forgotten it; rather, they never encoded the information in the first place. *Encoding failure* occurs when the information was never entered into long-term memory.

As an example of encoding failure, think about what the U.S. penny looks like. In one study, researchers showed 15 versions of the penny to participants and asked them which was correct (Nickerson & Adams, 1979). Look at the pennies in Figure 8.20 (but do not read the caption yet) and see if you can tell which one is the real penny. Most people do not do well on this task. Unless you are a coin collector, you likely have not encoded a lot of specific details about pennies. You may have encoded just enough information to distinguish them from other coins (pennies are copper-colored, dimes and nickels are silver-colored; pennies fall between the sizes of dimes and quarters).

The penny exercise illustrates that we encode and enter into long-term memory only a small portion of our life experiences. In a sense, then, encoding failures really are not cases of forgetting; they are cases of not remembering.

Retrieval Failure

Problems in retrieving information from memory are clearly examples of forgetting (Gardiner, 2007; Spear, 2007). Psychologists have theorized that the causes of retrieval failure include problems with the information in storage, the effects of time, personal reasons for remembering or forgetting, and the brain's condition (Miller & Matzel, 2006; Sweatt, 2007).

Interference Interference has been proposed as one reason that people forget (Sangha & others, 2005). **Interference theory** states that people forget not because memories are lost from storage but because other information gets in the way of what they want to remember.

There are two kinds of interference: proactive and retroactive. **Proactive interference** occurs when material that was learned earlier disrupts the recall of material learned later (Hedden & Yoon, 2006). Remember that *pro-* means "forward in time." For example, suppose you had a good friend 10 years ago named Prudence and that last night you met someone named Patience. You might find yourself calling your new friend Prudence because the old information (Prudence) interferes with retrieval of new information (Patience). **Retroactive interference** occurs when material learned later disrupts the retrieval of information learned earlier (Delprato, 2005). Remember that *retro-* means "backward in time." Suppose you have lately become friends with Ralph. In sending a note to your old friend Raul, you might mistakenly address it to Ralph because the new information (Ralph) interferes with the old information (Raul). Figure 8.21 depicts another example of proactive and retroactive interference.

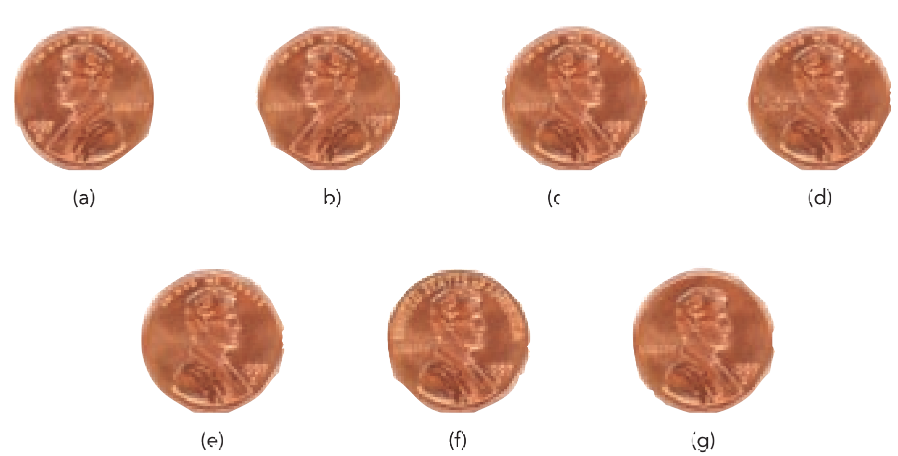


FIGURE 8.20
Which Is a Real U.S. Penny? In the original experiment, 15 versions of pennies were shown to participants: only 1 was an actual U.S. penny. Included here are only 7 of the 15 versions, and as you likely can tell, this still is a very difficult task. *Why?* By the way, the actual U.S. penny is (c).

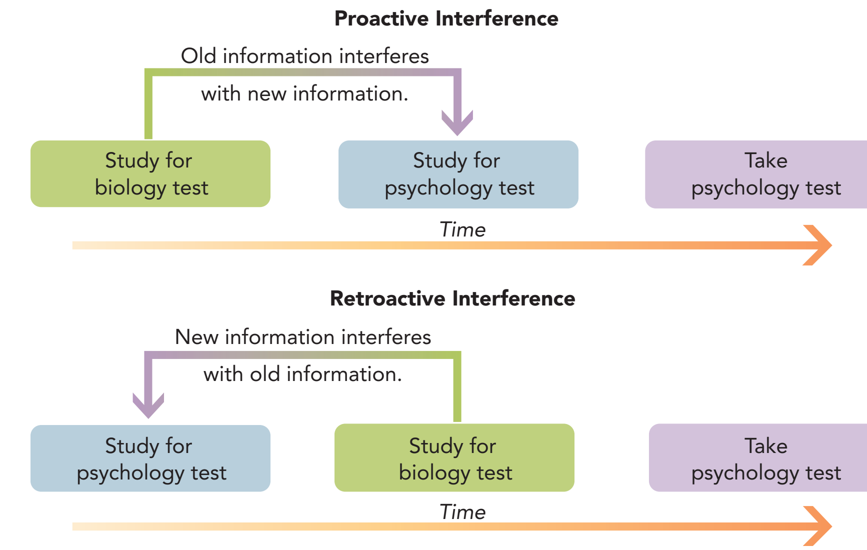


FIGURE 8.21
Proactive and Retroactive Interference *Pro-*means "forward"; in proactive interference, old information has a forward influence by getting in the way of new material learned. *Retro-* means "backward"; in retroactive interference, new information has a backward influence by getting in the way of material learned earlier.

Proactive and retroactive interference might both be explained as problems with retrieval cues. The reason the name Prudence interferes with the name Patience and the name Ralph interferes with the name Raul might be that the cue you are using to remember the one name does not distinguish between the two memories. For example, if the cue you are using is "my good friend," it might evoke both names. The result might be retrieval of the wrong name or a kind of blocking in which each name interferes with the other and neither comes to mind. Retrieval cues (such as "friend" in our example) can become overloaded, and when that happens we are likely to forget or to retrieve incorrectly.

Decay and Transience Another possible reason for forgetting is the passage of time. **Decay theory** states that when something new is learned, a neurochemical "memory trace" is formed, but over time this trace tends to disintegrate. Decay theory suggests that the passage of time always increases forgetting.

Memory researcher Daniel Schacter (2001) refers to the forgetting that occurs with the passage of time as *transience*. As an example of transience, consider the dramatic conclusion, on October 3, 1995, to the most sensational criminal trial in recent times: A jury acquitted former football star O. J. Simpson of murdering his wife and her friend. The Simpson verdict seemed like just the kind of flashbulb memory that most people would retain vividly for years to come. In one research study, undergraduate students provided detailed accounts of how they learned about the Simpson verdict, shortly after it was announced (Schmolck, Buffalo, & Squire, 2000). However, 15 months later, only half remembered the details, and nearly 3 years after the verdict, less than 30 percent of the students' memories were accurate.

Memories often do fade with the passage of time, but decay or transience alone cannot explain forgetting. For example, under the right retrieval conditions, memories that seem to have been forgotten can be retrieved. You might have forgotten the face or name of someone in your high school class, but when you return to the setting in which you knew the person, you may remember.

Tip-of-the-Tongue Phenomenon One glitch in retrieving information that we are all familiar with is the *tip-of-the-tongue phenomenon,* or *TOT state*. It is a type of "effortful retrieval" that occurs when people are confident that they know something but they cannot

interference theory States that people forget not because memories are actually lost from storage but because other information gets in the way of what they want to remember.

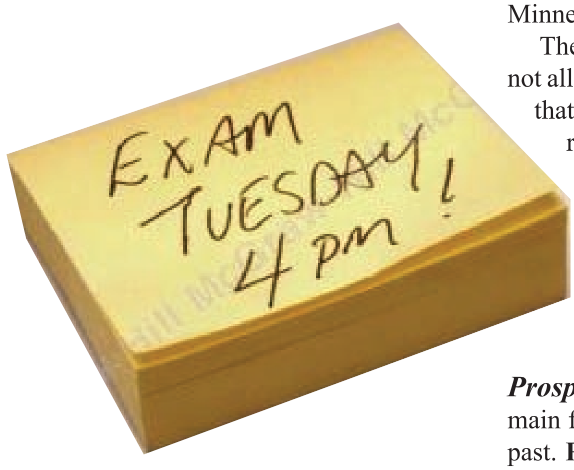
proactive interference Occurs when material that was learned earlier disrupts the recall of material learned later.

retroactive interference Occurs when material learned later disrupts the retrieval of information learned earlier.

decay theory Theory stating that when something new is learned, a neurochemical "memory trace" is formed, but over time this trace tends to disintegrate.

quite pull it out of memory (James, 2006; Maril & others, 2005). People in a TOT state usually can successfully retrieve characteristics of the word, such as the first letter and the number of syllables, but cannot retrieve the word itself.

In one study of the TOT state, participants viewed photographs of famous people and were asked to say their names (Yarmey, 1973). The researcher found that people tended to use two strategies to try to retrieve the name of a person they thought they knew. One strategy was to pinpoint the person's profession. For example, one participant correctly identified the famous person as an artist, but the artist's name, Picasso, remained elusive. Another retrieval strategy was to repeat initial letters or syllables—such as *Monetti, Mona, Magett, Spaghetti,* and *Bogette* in the attempt to identify stage and screen star Liza Minnelli.



The TOT state arises because a person can retrieve some of the desired information but not all of it (Maril, Wagner, & Schacter, 2001; Schacter, 1996, 2001). For example, imagine that you are at a college social event and spot two people standing together. You easily recall that one of them is Barbara. You know that you have seen the other person before and are sure his name begins with a *B* (a good retrieval cue). You are certain that you know his name, although you cannot remember it at the moment. But maybe when you were introduced to him, you did not pay enough attention to his name to remember more than the first letter. Your confidence in the retrieval cue can induce a strong—sometimes spurious—feeling of knowing other information (in this case, the name) that you actually have not stored in memory.

Prospective Memory: Remembering (or Forgetting) When to Do Something The main focus of this chapter has been on **retrospective memory,** which is remembering the past. **Prospective memory** involves remembering information about doing something in the future; it includes memory for intentions (McDaniel & Einstein, 2007). Prospective memory includes both *timing*—when we have to do something—and *content*—what it is we have to do.

A distinction can be made between time-based and event-based prospective memory. *Time-based* prospective memory is your intention to engage in a given behavior after a specified amount of time has gone by (such as an intention to make a phone call to someone in 1 hour). In *event-based* prospective memory, you engage in the intended behavior when it is elicited by some external event or cue (such as giving a message to your roommate when you see her). The cues available in event-based prospective memory make it more effective than time-based prospective memory (McDaniel & Einstein, 2007; Seifert & Patalano, 2001).

Some failures in prospective memory are referred to as "absentmindedness." We are more absentminded when we become preoccupied with something else, are distracted by something, or are under a lot of time pressure (Matlin, 2001). Absentmindedness often involves a breakdown between attention and memory storage (Schacter, 2001). Absentmindedness may especially be a problem when we have too little time or are too distracted to elaborately encode something we need to remember. We spend a great deal of our lives on autopilot, a state that helps us to perform routine tasks effectively but also makes us vulnerable to absentminded errors. Fortunately, research has shown that our goals are encoded into memory along with the features of situations that would allow us to pursue them. Our memories, then, prepare us to recognize when a situation presents an opportunity to achieve those goals (Seifert & Patalano, 2001).

Continuing research on prospective memory is providing new clues that will help people improve their memories. In one study, individuals were given 4 minutes to recall what they did yesterday, last week, or last year (retrospective memories) and 4 minutes to recall what they intended to do tomorrow, next week, or next year (prospective memories) (Maylor, Chater, & Brown, 2001). More prospective memories were recalled than retrospective memories. Researchers also have found that older adults perform worse on prospective memory tasks than younger adults do, but typically these findings are true only for artificial lab tasks (West & Bowry, 2005). In real life, older adults generally perform as well as younger adults in terms of prospective memory (Rendell & Craik, 2000). Generally, prospective

retrospective memory Remembering the past.

prospective memory Remembering information about doing something in the future, including memory for intentions.

Alabama businesswoman Patsy Cannon was in a car crash in 1986. Her injury was so severe that it left her with retrograde amnesia, and she had to relearn virtually everything she used to know. Cannon did not even recognize her own daughter. (Left) *Cannon in 1986 just prior to the car crash.* (Right) *Cannon in a recent photo. Referring to her life before the accident, she has said, "That person is dead; I am a new person."*

memory failure (forgetting to do something) occurs when retrieval is a conscious, effortful (rather than automatic) process (Henry & others, 2004).

Amnesia Recall the case of H. M. in the discussion of explicit and implicit memory. In H. M.'s surgery, the part of his brain that was responsible for laying down new memories was damaged beyond repair. The result was **amnesia,** the loss of memory. Although some types of amnesia clear up over time, H. M.'s amnesia endured.

H. M. suffered from **anterograde amnesia,** a memory disorder that affects the retention of new information and events (*antero-* indicates amnesia that moves forward in time) (Gilboa & others, 2006). What he learned before the surgery (and thus before the onset of amnesia) was not affected. For example, H. M. could identify his friends, recall their names, and even tell stories about them—*if* he had known them before surgery. People who met H. M. after surgery remained strangers, even if they spent thousands of hours with him. H. M.'s postsurgical experiences were rarely encoded in his long-term memory.

Amnesia also occurs in a form known as **retrograde amnesia,** which involves memory loss for a segment of the past but not for new events (*retro-* indicates amnesia that moves back in time) (Gold, 2006). Retrograde amnesia is much more common than anterograde amnesia and frequently occurs when the brain is assaulted by an electrical shock or a physical blow—such as a head injury to a football player. In contrast to anterograde amnesia, in retrograde amnesia the forgotten information is *old*—it occurred prior to the event that caused the amnesia—and the ability to acquire new memories is not affected. Sometimes individuals have both anterograde and retrograde amnesia.

amnesia The loss of memory.

anterograde amnesia A memory disorder that affects the retention of new information and events.

retrograde amnesia A memory disorder that involves memory loss for a segment of the past but not for new events.

REVIEW AND SHARPEN YOUR THINKING

5 Describe how the failure of encoding and retrieval are involved in forgetting.

- Define encoding failure.
- Discuss four reasons for retrieval failure.

Think about three or four instances recently in which you were unable to remember something. What principle of forgetting do you think best explains your failure to remember in each case?

6 Study Tips from the Science of Memory

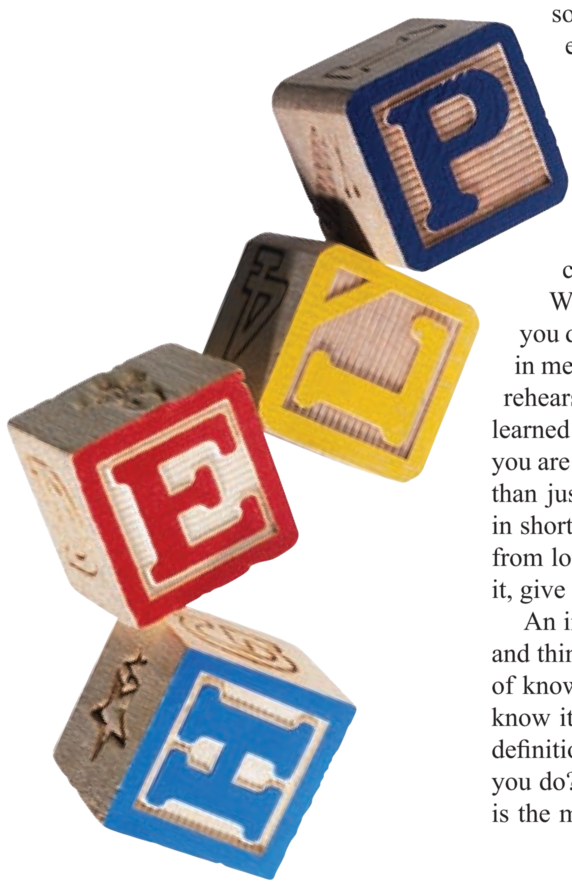
Evaluate study strategies based on an understanding of memory.

Now that you are familiar with the basic processes of memory, how can you apply your knowledge to improving your academic performance? No matter what model of memory we use, the message is clear: We can improve our memory for material by thinking deeply about it and connecting the information to other things we know. Perhaps the one most well-connected node or most elaborate schema to which we can relate something is the self—what we know and think about ourselves. To make something more meaningful and to secure its place in memory, we must make it matter to ourselves.

If we think about memory as a physical event in the brain, we can see that memorizing material is like training a muscle. Repeated recruitment of sets of neurons creates the connection we want to have available at exam time and throughout our lives.

Encoding, Rehearsal, and Retrieval of Course Material

Before you engage the powerful process of memory, the first step in improving your academic performance is to make sure the information you are studying is accurate and well organized. You should review your course notes routinely and catch potential errors and ambiguities early. There is no sense in memorizing inaccurate or incomplete information. Second, organize the material in a way that will allow you to commit it to memory effectively. You will remember information better if you consciously organize it while trying to absorb it. Arrange information, rework material, and give it a structure that will help you to remember it. One organizational technique is to use a hierarchy such as an outline. You might also devise a concept map, which draws on semantic-network theory, or create analogies (such as the earlier comparison of retrieval from long-term memory to a finding a book in the library) that take advantage of your preexisting schemas.



Once the material to be remembered is accurate and well organized, it is time to memorize. The first step in successfully memorizing material is to process it effectively so that it will be stored in long-term memory. Although some types of information are encoded automatically, the academic learning process usually requires considerable effort (Bruning & others, 2004). Recall that encoding involves paying attention, processing information at an appropriate level, elaborating, and using imagery. Learning and studying in a way that actively engages memory with the material is vital. Encoding material is not simply something that you should do before a test. Rather, during class, while reading, or in discussing issues, you are given—and should take advantage of—your first opportunity to create associations to course material.

While learning material initially, relate it to your life, and attend to examples that help you do just that. After class, rehearsal of the course material over time helps to solidify it in memory. Some students find that rewriting their notes is a good form of rehearsal. But rehearsal does not have to be a solitary exercise. Talking to people about what you have learned and how it is important to real life will help to reinforce memory. Keep in mind that you are more likely to remember information over the long term if you understand it rather than just mechanically rehearse and memorize it. Rehearsal works well for information in short-term memory, but when you need to encode, store, and then retrieve information from long-term memory, it is much less efficient. Thus, for most information, understand it, give it meaning, elaborate on it, and personalize it.

An important next step is to test yourself. It is not enough simply to look at your notes and think, "Oh, yes, I know this!" Remember, sometimes recognition instills a false sense of knowing. If you look at a definition and it seems so familiar that you are certain you know it, *test yourself*. What happens when you close the book and try to reconstruct the definition? Check your personal definition with the technical one in the book. How did you do? While reading and studying, ask yourself other questions as well, such as "What is the meaning of what I just read?" "Why is this important?" and "What is an example of the concept I just read about?" When you have made a concerted effort to ask yourself questions about what you have read or about an activity in class, you will expand the number of associations you make with the information you will need to retrieve later.

Mnemonic Strategies

Another tip for improving memory performance for course materials is to use mnemonic strategies. *Mnemonics* are specific visual and/or verbal memory aids. Following are three types of mnemonic devices:

- *Method of loci*: You develop an image of items to be remembered and then store them mentally in familiar locations (which is what *loci* means). Rooms of houses or stores on a street are common locations used in this memory strategy. For example, if you need to remember a list of brain structures, you can mentally place them in the rooms of a house you are familiar with, such as the entry hall, the living room, the dining room, and the kitchen. Then, when you need to retrieve the information, you imagine the house, mentally go through the rooms, and retrieve the concepts.
- *Keyword method*: You attach vivid imagery to important words. For example, to remember that the limbic system consists of two main regions—amygdala and hippocampus—you might imagine two legs (limbs) (limbic system) ambling (amygdala) like a hippo (hippocampus).
- *Acronyms*: To form an acronym, you create a word from the first letters of items to be remembered. For example, *HOMES* can be used to remember the Great Lakes: *H*uron, *O*ntario, *M*ichigan, *E*rie, and *S*uperior. An acronym commonly used to remember the sequence of colors in the light spectrum is the name of an imaginary man named *ROY G. BIV: R*ed, *O*range, *Y*ellow, *Gre*en, *B*lue, *I*ndigo, and *V*iolet.

Many experts on memory and study skills recommend using mnemonics mainly when you need to memorize a list of items or specific facts. However, in most cases, techniques that promote memory by developing an understanding of the material are better than rote memorization.

If you are genuinely seeking to improve your memory performance, also keep in mind that the brain is a physical organ. Perhaps the best way to promote effective memory storage is to make sure that your brain is able to function at maximum capacity. For most of us, that means being well rested, well nourished, and free of mind-altering substances.

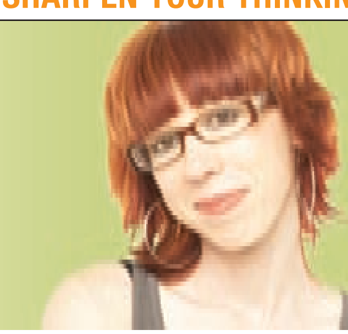
So, you have studied not just hard but deeply, elaborating on important concepts and committing lists to memory. You have slept well and eaten a nutritious breakfast, and now it is time to take the exam. How can you best retrieve the essential information? One way to improve the accuracy and efficiency of retrieval is through the use of retrieval cues. Of course, one potential retrieval cue is out of the question—your class notes have been put aside. But remember that the exam itself is full of questions about topics that you have thoughtfully encoded. Recall that research on long-term memory has shown that material that has been committed to memory is there for a very long time—even among those who may experience a moment of panic when the test is handed out. Focus on the concepts on the test. Use them to trigger your insights.

REVIEW AND SHARPEN YOUR THINKING

6 Evaluate study strategies based on an understanding of memory.

- Describe effective encoding, rehearsal, and retrieval strategies for recalling course material.
- Explain what a mnemonic strategy is and give some examples.

Get together with three or four students in this class and compare your note-taking and study strategies. How are your strategies similar to or different from those of the other students? What did you learn from the comparison and this chapter about how to study more effectively?



7 Memory and Health and Wellness

Discuss the multiple functions of memory in human life.

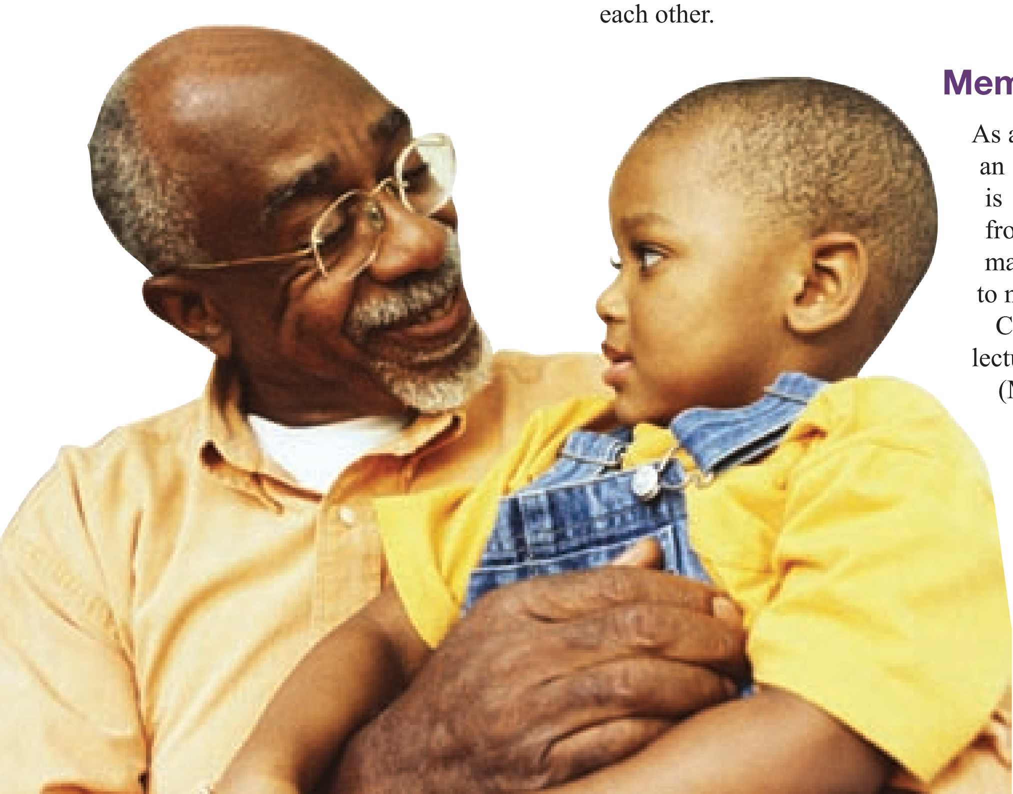
We began this chapter by recognizing that memory is essential to many aspects of human life, from waiting on tables to performing academic tasks. Acts of memory—remembering to take your vitamins and medication, or to stick to a diet—are also important for your good health. But memory is more than an internalized "to do" list, as we now consider.

The Vital Role of Autobiographical Memory

Memory serves multiple functions. Autobiographical memory, for example, may be one of the most important aspects of human life (Cabeza & St. Jacques, in press). For instance, one of the many functions that autobiographical memory serves is to allow us to learn from our experiences (Pillemer, 1998). In autobiographical memory, we store the lessons we have learned from life. These memories become a resource to which we can turn when faced with life's difficulties.

Autobiographical memory also allows us to understand ourselves and provides us with a source of identity (Alea & Bluck, 2003; Singer, 2004). In his studies of self-defining autobiographical memories, Jefferson Singer and his colleagues maintain that these internalized stories of personal experience serve as signs of the meaning we have created out of our life experience and give our lives coherence (Conway, Singer, & Tagini, 2004; Singer, 2004; Singer & Blagov, 2004). Autobiographical memories are one domain in which the notion that each human being is truly unique—"like a snowflake," as your kindergarten teacher may have noted—is supported. No matter how similar two people are, the storehouse of life experience that is represented in autobiographical memory is genuinely each person's own.

A final function of autobiographical memory is its role in social bonding. The social function of autobiographical memory may be its most vital (Alea & Bluck 2003; Bruce, 1989; Nelson, 1993). Our memories are valuable not just as indicators of lessons learned or identity, but also as a way to share a part of ourselves with others. Sharing personal experience is a way to foster intimacy, create bonds, and deepen existing ones. When we know a person's most cherished autobiographical memory, we know that she is no longer just an acquaintance but clearly a friend. To the extent that social bonds are necessary for survival, it makes sense that human beings can remember and share those memories with each other.



Our memories are an intimate way to share a part of ourselves with others, as a grandfather does with his grandchild.

Memory and Aging

As a process that is rooted in the brain, memory is also an indicator of brain functioning. Preserving memory is of vital importance as we age. A strong message from research on aging and memory is that, as for many things in life, the phrase "Use or lose it!" applies to memory.

Consider the case of Richard Wetherill, a retired lecturer and an uncommonly good chess player (Melton, 2005). Wetherill was so skilled that he was able to think eight moves ahead in a chess match. At some point, he noticed that he was having trouble playing chess—he was able to think only five moves ahead. He was sure that something was seriously wrong with himself, despite his wife's assurances that she noticed no changes. A battery of cognitive tests revealed no abnormalities, and a brain scan was similarly reassuring. Two years later, Wetherill was dead, and the autopsy showed a brain ravaged by Alzheimer disease. Brain damage of this sort should indicate a person who was incapable of coherent thought. Yet Wetherill's symptoms had been limited to a small decline in his chess ability.

His case is surprising but also surprisingly typical. Individuals who lead active intellectual lives seem to be protected against the mental decline typically associated with age. Indeed, research has shown that individuals who are educated, have high IQs, and remain mentally engaged in complex tasks tend to cope better with a variety of assaults to the brain, including Alzheimer disease, stroke, head injury, and even poisoning with neurotoxins (Melton, 2005). Some research has suggested that an active mental life leads to the accumulation of a "cognitive store"—an emergency stash of mental capacity that allows individuals to avoid the negative effects of harm to the brain.

Yaakov Stern found that among a group of individuals with Alzheimer disease who appeared to be equal in terms of their outward symptoms, those who were more educated were actually suffering from much worse brain damage—yet they were functioning at a level similar to others with relatively less damage (Stern & others, 1992). Stern and his colleagues (2004) have also shown that intellectual pursuits such as playing chess and reading reduce the severity of Alzheimer symptoms. Apparently, a lifetime of mental activity and engagement produces this cognitive reserve that allows the brain to maintain its ability to recruit new neural networks that compensate for damage. These brains are better able to move to a backup plan to maintain the individual's level of functioning (Andel & others, 2005). The clear message from these studies is the importance of building up a cognitive reserve by staying mentally active throughout life. In addition to educational achievement, staying physically active also seems to play a role in maintaining a sharp mind (Kramer, Fabiani, & Colcombe, 2006; Sumic & others, 2007).

Memory and Everyday Life

Before we leave the science of memory, let's consider the role of memory in shaping meaningful experiences in daily life. Think of the most meaningful event of your life. Clearly, that event is one that you remember, among *all* the things you have experienced in your life. We all have vivid autobiographical memories that stand out as indicators of meaning (such as those studied by Jefferson Singer that were discussed above).

But everyday life is filled with potentially remarkable moments—a beautiful sunrise, a delicious meal prepared just for you, an unexpected telephone call from a friend. Experiencing everyday life in its richness requires us to be available and engaged. Sometimes the daily chores and hassles of life lead us to feel that we are just going through the motions. This sort of mindless living may be a way to survive, but it is unlikely to be a way to thrive. The processes of attention and encoding that we have explored in this chapter suggest that actively engaging in life—investing ourselves in the events of the day (Cantor & Sanderson, 1999)—is the way we can be assured that our life stories are rich and nuanced. That way, when someone asks, "So, tell me about yourself," we have a story to tell.

REVIEW AND SHARPEN YOUR THINKING

7 Discuss the multiple functions of memory in human life.

- Describe the role of autobiographical memory in the experience of identity and social relationships.
- Discuss some strategies involved in maintaining healthy memory function throughout life.
- Explain the relationship among mindful living, memory, and the experience of meaning in life.

Do you know someone who has been affected by Alzheimer disease? How have memory changes influenced the person's life and the lives of his or her loved ones?

SUMMARY

1 THE NATURE OF MEMORY

Identify the three phases of memory.

Memory is the retention of information over time through encoding, storage, and retrieval—the three phases of memory. Encoding involves getting information into storage, storage consists of retaining information over time, and retrieval involves taking information out of storage.

2 MEMORY ENCODING

Explain how memories are encoded.

Attention

To begin the process of memory encoding, we have to attend to information. Selective attention is a necessary part of encoding. Memory is often negatively influenced by divided attention.

Levels of Processing

Levels of processing theory states that information is processed on a continuum from shallow (sensory or physical features are encoded) to intermediate (labels are attached to stimuli) to deep (the meanings of stimuli and their associations with other stimuli are processed). Deeper processing produces better memory.

Elaboration

Elaboration, the extensiveness of processing at any given level of memory, improves memory.

Imagery

Using imagery, or mental pictures, as a context for information can improve memory.

3 MEMORY STORAGE

Discuss how memories are stored.

Sensory Memory

The Atkinson-Shiffrin theory describes memory as a three-stage process: sensory memory, short-term memory, and long-term memory. Sensory memory holds perceptions of the world for only an instant, not much longer than the brief time the person is exposed to visual, auditory, and other sensory input. Visual sensory memory (iconic memory) retains information about one-fourth of a second; auditory sensory memory (echoic memory), for several seconds.

Short-Term Memory

Short-term memory is a limited-capacity memory system in which information is usually retained for as long as 30 seconds. Short-term memory's limitation is $7 + 2$ bits of information. Chunking and rehearsal can benefit short-term memory. Baddeley's concept of working memory characterizes short-term memory as more active and complex than Atkinson and Shiffrin proposed. Baddeley's model of working memory has three components: a central executive and two assistants (phonological loop and visuospatial working memory).

Long-Term Memory

Long-term memory is a relatively permanent type of memory that holds huge amounts of information for a long period of time. Long-term memory can be divided into two main subtypes: explicit and implicit memory. Explicit memory is the conscious recollection of information, such as specific facts or events. Implicit memory affects behavior through prior experiences that are not consciously recollected. Explicit memory has two dimensions. One dimension includes episodic memory and semantic memory. The other dimension includes retrospective memory and prospective memory. Implicit memory is multidimensional, too. It includes systems for procedural memory, priming, and classical conditioning.

4 MEMORY RETRIEVAL

Summarize how memories are retrieved.

Serial Position Effect

The serial position effect is the tendency for items at the beginning and the end of a list to be remembered better than items in the middle of a list. The primacy effect refers to better recall for items at the beginning of the list. The recency effect refers to better memory for items at the end of a list.

Retrieval Cues and the Retrieval Task

Memory retrieval is easier when effective cues are present. Another factor in effective retrieval is the nature of the retrieval task. Simple recognition of previously remembered information in the presence of cues is generally easier than recall of the information. The encoding specificity principle states that information present at the time of encoding or learning tends to be effective as a retrieval cue. In many instances, people recall information better when they attempt to recall it in the same context or internal state in which they learned the information. These processes are referred to as context-dependent and state-dependent memory, respectively. Retrieval also benefits from priming, which activates particular connections or associations in memory. The tip-of-the-tongue phenomenon occurs when we cannot quite pull something out of memory.

Special Cases of Retrieval

Five special cases of retrieval are autobiographical memory, emotional memory, memory for trauma, repressed memory, and eyewitness testimony. Autobiographical memory is a person's recollections of his or her life experiences. Autobiographical memory has three levels: (1) life time periods, (2) general events, and (3) event-specific knowledge. Biographies of the self connect the past and the present to form our identity. Emotional memories may be especially vivid and enduring. Particularly significant emotional memories, known as flashbulb memories, capture emotionally significant events that people often recall with more accuracy and vivid imagery than they do everyday events. Memory for personal trauma also is usually more accurate than memory for ordinary events, but it, too, is subject to distortion and inaccuracy. People tend to remember the core information about a personal trauma but might distort some of the details. Personal trauma can cause individuals to repress emotionally laden information so that it is not accessible to consciousness. Repression does not erase a memory; it just makes it far more difficult to retrieve. Eyewitness testimony may contain errors due to memory decay or bias. Wording of questions and lineup instructions are examples of circumstances that influence eyewitness testimony.

5 FORGETTING

Describe how the failure of encoding and retrieval are involved in forgetting.

Encoding Failure

Encoding failure is forgetting information that was never entered into long-term memory.

Retrieval Failure

Retrieval failure can occur for at least four reasons. Interference theory states that we forget not because memories are lost from storage but because other information gets in the way of what we want to remember. Interference can be proactive or retroactive. Decay theory states that when something new is learned, a neurochemical memory trace is formed, but over time this chemical trail tends to disintegrate; the term for the phenomenon of memories fading with the passage of time is *transience*. Motivated forgetting, which occurs when people want to forget something, is common when a memory becomes painful or anxiety-laden, as in the case of emotional traumas such as rape or physical abuse. Amnesia, the physiologically based loss of memory, can be anterograde, affecting the retention of new information or events; retrograde, affecting memories of the past but not new events; or both.

6 STUDY TIPS FROM THE SCIENCE OF MEMORY

Evaluate study strategies based on an understanding of memory.

Encoding, Rehearsal, and Retrieval of Course Material

Effective encoding strategies when studying include being a good time manager and planner, paying attention and minimizing distraction, understanding the material rather than rote memorization, asking yourself questions, and taking good notes. Research on memory suggests that the best way to remember course material is to relate it to many different aspects of your life.

Mnemonic Strategies

Effective mnemonic strategies for remembering and retrieving course material include the method of loci, the keyword method, and the use of acronyms to remember lists.

7 MEMORY AND HEALTH AND WELLNESS

Discuss the multiple functions of memory in human life.

The Vital Role of Autobiographical Memory

Autobiographical memories, particularly self-defining memories, play a significant role in identity and social relationships. Our self-defining memories provide a unique source of identity, and sharing those memories with others plays a role in social bonding.

Memory and Aging

Engaging in challenging cognitive tasks throughout life can stave off the effects of age on memory and lessen the effects of Alzheimer disease.

Memory and Everyday Life

Engaging in everyday life means living memorably. Mindfulness to life events provides a rich resource of experiences upon which to build a storehouse of autobiographical memory.

Key Terms

memory, p. 26
encoding, p. 27
levels of processing, p. 28
elaboration, p. 28
storage, p. 30
Atkinson-Shiffrin theory, p. 31
sensory memory, p. 31
short-term memory, p. 32
working memory, p. 33
long-term memory, p. 34
explicit memory (declarative memory), p. 35
episodic memory, p. 35
semantic memory, p. 36
implicit memory (nondeclarative memory), p. 36
procedural memory, p. 36
priming, p. 37
schema, p. 39
script, p. 40
connectionism (parallel distributed processing [PDP]), p. 40
retrieval, p. 44
serial position effect, p. 45
motivated forgetting, p. 50
interference theory, p. 54
proactive interference, p. 54
retroactive interference, p. 54
decay theory, p. 55
retrospective memory, p. 56
prospective memory, p. 56
amnesia, p. 57
anterograde amnesia, p. 57
retrograde amnesia, p. 57

Apply Your Knowledge

1. Take the key terms in a chapter of this text that you have not yet read. Spend 20 to 30 minutes trying to learn half of the words in an environment filled with distractions (such as the cafeteria at lunchtime or a crowded coffeehouse). Then spend the same amount of time trying to learn the other half of the words in a distraction-free environment. Test yourself later on your memory for the words. Which list was easier to remember? Are there distractions in your current study environment? How do you think eliminating them would affect your memory?
2. Some people believe that they have memories from past lives stored in their brain. Consider each of the ways the brain may store memory. Are any of these compatible with memories from past lives?
3. It is sometimes difficult to believe that our memories are not as accurate as we think. To test your ability to be a good eyewitness, visit one of the following websites:

   http://www.pbs.org/wgbh/pages/frontline/shows/dna/

   http://www.psychology.iastate.edu/faculty/gwells/theeyewitnesstest.html

   Did this exercise change your opinion of the accuracy of eyewitness testimony?
4. Think about the serial position effect. What does it suggest about how you should organize your study time? When should you study information you think is most important?
5. For 1 week, keep a diary of the most memorable events of your day. Review the list at the end of the week. Do you still remember those events? Are they mostly negative or positive? What aspects of your life seem to be most memorable to you? What are some domains of life where you might work on being more "mindful"?