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MEMORY

CHAPTER OUTLINE

The charm, one might say, the genius of memory is that it is choosy, chancy, and temperamental.

—Elizabeth Boren

Some people are famous for their extraordinary remembering; others, for their extraordinary forgetting. Consider Rajan Mahadevan, who at age 5 sauntered outside one day while his parents entertained about 40 to 50 guests at a party. Rajan studied the guests' parked cars, returned to the party, and then recited all the license plate numbers from memory, matching each to the proper guest in the order they had parked. While in college, Rajan set a world record by flawlessly recalling the first 31,811 digits of pi (π)*. He averaged 3.5 digits per second!*

Rajan left India to attend graduate school at Kansas State University, where a team of psychologists (at Rajan's request) studied his memory abilities. They describe another of his remarkable feats. Suppose you have a sheet of paper containing the first 5,000 digits of pi, arranged in 500 blocks of 10 digits. Pick any block, start reading the first few digits, and before you can finish, Rajan will recite the remaining digits from memory (Thompson et al., 1993). How does he do it? "Rajan said . . . that being asked to describe how he learned numbers was like being asked to describe how he rode a bicycle. He knew how to do both tasks, but he found it difficult to describe either process" (p. 13).

In most other ways, however, Rajan's memory is ordinary. Indeed, he uses a grocery list to help him remember what to buy at the market, and as he notes, "Unless I put my glasses, wallet and keys together near the door before I leave to start my day, I will surely forget them" (Harris, 2002).

You are about to meet H. M., who at age 27 had most of his hippocampus and surrounding brain tissue surgically removed to reduce his severe epileptic seizures. The operation succeeded, but it unexpectedly left H. M. with amnesia*, or memory loss.*

When you first meet H. M. he might appear normal, for he is bright and has retained good language and social skills. He can discuss his childhood, teens, and early 20s, for those memories are intact. Indeed, for the most part at age 27, H. M.'s amnesia did not rob him of his past. Rather, it robbed him of his future.

H. M. lost the ability to form new memories that he can consciously recall. Typically, once an experience or fact leaves his immediate train of thought, he cannot remember it. Spend the day with H. M., depart and return minutes later, and he will not recall having met you. He reads magazines over and over as if he has never seen them before. A favorite uncle has died, but H. M. cannot remember. Thus every time H. M. asks how his uncle is, he experiences shock and grief as though it were the first time he learned of his uncle's death.

H. M.'s surgery took place in 1953, and researchers have studied him for over 40 years (Xu & Corkin, 2001). No matter how many years pass, H. M.'s memory for events contains little after 1953. Even his sense of identity is frozen in time. H. M. recalls himself looking like a young man but cannot remember the aging image of himself that he sees in the mirror. H. M. describes what his existence is like: "Every day is alone in itself. . . . You see, at this moment, everything looks clear to me, but what happened just before? It's like waking from a dream. I just don't remember" (Milner, 1970, p. 37).

Memory *refers to the processes that allow us to record, store, and later retrieve experiences and information*. Memory adds richness and context to our lives, but even more fundamentally, it allows us to learn from experience and thus adapt to changing environments. From an evolutionary standpoint, without the capacity to remember we would not have survived as a species.

As the cases of Rajan and H. M. illustrate, memory is complex. How did Rajan remember over 30,000 digits of pi? Why is it, as Figure 7.1 shows, that H. M. can remember how to perform new tasks yet swear each time he encounters these tasks that he has never seen them before? In this chapter we explore the fascinating nature of memory.

REMEMBERING: MEMORY AS INFORMATION PROCESSING

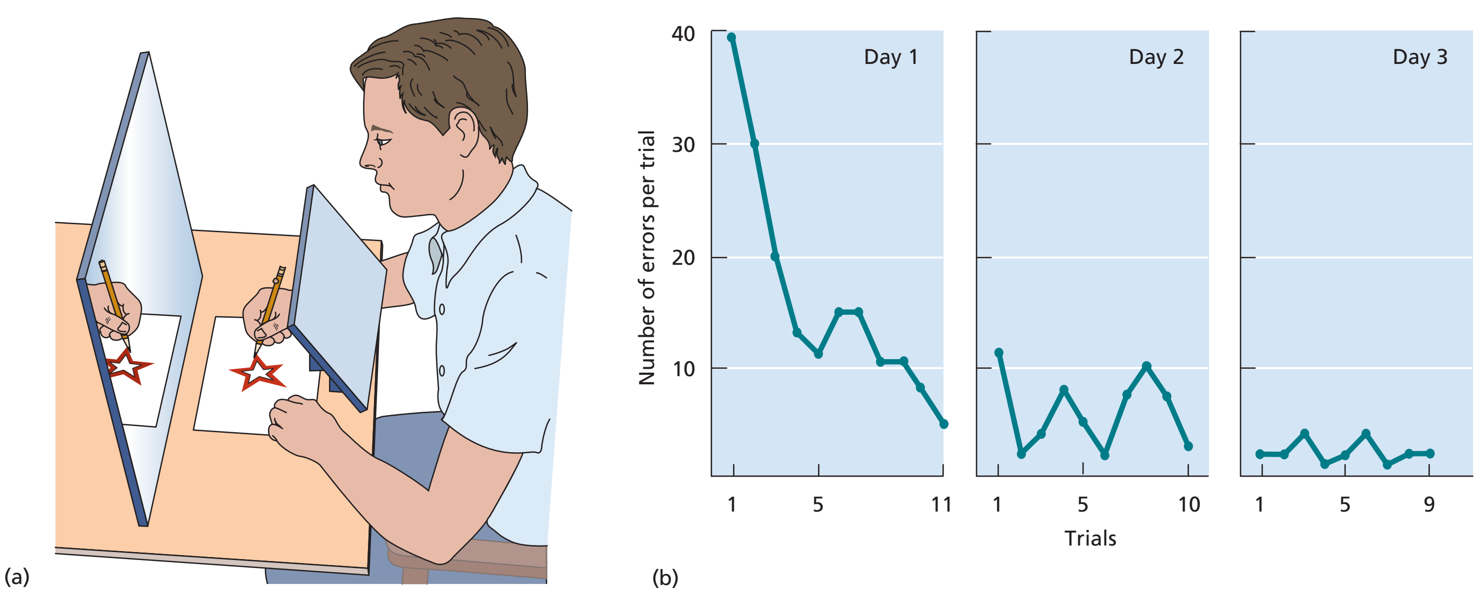
Psychological research on memory has a rich tradition, dating back to late 19th-century Europe. By the 1960s, computer advancements and the cognitive revolution in psychology led to a new metaphor that continues to guide memory research: the mind as a processing system that encodes, stores, and retrieves information. **Encoding** *refers to getting information into the system by translating it into a neural code that your brain processes*. This is a little like what happens when you type on a computer keyboard, as your keystrokes are translated into an electrical code that the computer can understand and process. **Storage** *involves retaining information over time*. Once in the system, information must be filed away and saved, as happens when a computer stores information temporarily in RAM (remote access memory) and more permanently on a hard drive. Finally, **retrieval** *refers to processes that access stored information*. On a computer, retrieval occurs when you give a software command (e.g., "Open File") that transfers information from the hard drive back to RAM and the screen, where you can scroll through it. Keep in mind, however, that this analogy between human and computer is crude. For one thing, people routinely forget and distort information and sometimes "remember" events that never occurred (Loftus, 2003; Pickrell et al. 2003). Human memory is highly dynamic, and its complexity cannot be fully captured by any existing information-processing model.

Encoding, storage, and retrieval represent what our memory system does with information. Before exploring these processes more fully, let's examine some basic components of memory.

1. What is memory and how is it likened to an information-processing system?

FIGURE 7.1

(a) On this complex task, participants trace a pattern while looking at its mirror image, which shows their hand moving in the direction opposite to its actual movement. (b) H. M.'s performance on this task rapidly improved over time—he made fewer and fewer errors—indicating that he had retained a memory of how to perform the task. *Yet each time he performed it, he stated that he had never seen the task before and had to have the instructions explained again.* SOURCE: Adapted from Milner, 1965.



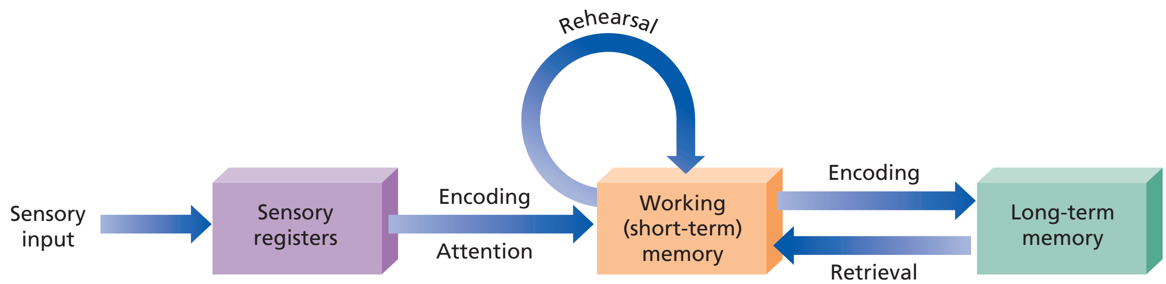


FIGURE 7.2

In this model, memory has three major components: (1) sensory registers, which detect and briefly hold incoming sensory information; (2) working (short-term) memory, which processes certain information received from the sensory registers and information retrieved from long-term memory; and (3) long-term memory, which stores information for longer periods of time. Source: Adapted from Atkinson & Shiffrin, 1968.

A Three-Stage Model

The model in Figure 7.2, developed by Richard Atkinson and Richard Shiffrin (1968) and subsequently modified, depicts memory as having three major components: sensory memory, working (short-term) memory, and long-term memory. Other memory models have been proposed, but this three-stage framework has been the most influential.

Sensory Memory

Sensory memory *briefly holds incoming sensory information*. It comprises different subsystems, called *sensory registers*, which are the initial information processors. Our visual sensory register is called the *iconic store*, and in 1960 George Sperling conducted a classic experiment to assess how long it holds information. On one task, Sperling arranged 12 letters in three rows and four columns, like those in Figure 7.3. He flashed the array on a screen for 1/20 of a second, after which participants immediately recalled as many letters as they could. Typically, they were able to recall only 3 to 5 letters.

Why was recall so poor? Did participants have too little time to scan all the letters, or had they seen the whole array, only to have their iconic memory fade before they could report all the letters? To find out, Sperling conducted another experimental condition. This time, just as the letters were flashed off, participants heard either a high-, medium-, or low-pitched tone, which signaled them to report either the top, middle, or bottom row of letters.

In this case, participants often could report all 4 letters in whichever row was signaled. Because they did not know which row would be signaled ahead of time, this implies that their iconic memory had stored an image of the whole array, and they now had time to "read" their iconic image of any one line before it rapidly disappeared. If this logic is correct, then participants should do poorly if the signaling tone is delayed. Indeed,

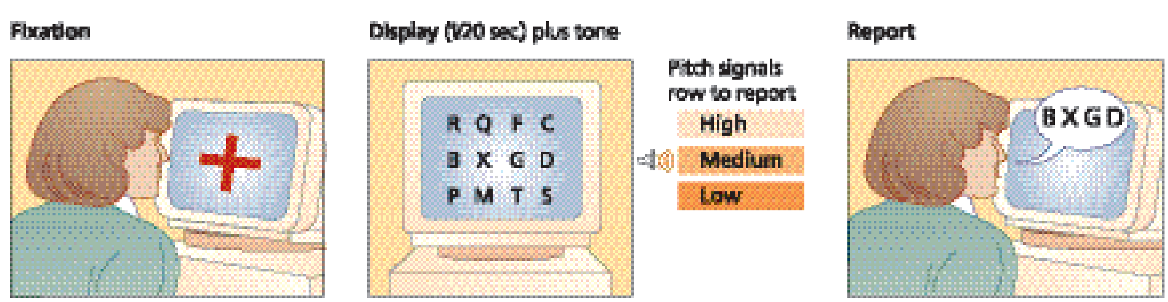


FIGURE 7.3

After a participant fixates on a screen, a matrix of letters is flashed for 1/20 of a second. In one condition, participants do not hear any tone and must immediately report as many letters as they can. In another condition, a high-, medium-, or low-pitched tone signals the participant to report either the top, middle, or bottom row. If the tone occurs just as the letters are flashed off, participants typically can report three or all four letters, no matter which row is signaled.

FIGURE 7.4

The arc of light that you see traced by a twirling sparkler, or the lingering flash that you see after observing a lightning bolt, results from the brief duration of information in iconic memory. Due to a slow camera shutter speed, this photo captures more arcs of light than you could actually see in this situation. Because your iconic memory stores complete information for only a fraction of a second, the actual image would quickly vanish.

with just a 1-second delay, performance was no better than without the tone. As Figure 7.4 illustrates, it is difficult, perhaps impossible, to retain complete information in purely visual form for more than a fraction of a second. In contrast, our auditory sensory register, called the *echoic store,* can hold information about the precise details of a sound for several seconds (Winkler et al., 2002).

Short-Term/Working Memory

Most information in sensory memory rapidly fades away. But, through selective attention, some information enters **short-term memory**, *a memory store that temporarily holds a limited amount of information*.

Memory Codes Once information leaves sensory memory, it must be represented by some type of code if it is to be retained in short-term memory. For example, the words that someone just spoke to you ("I like your new haircut") must somehow become represented in your mind. **Memory codes** *are mental representations of some type of information or stimulus*, and they can take various forms. We may try to form mental images *(visual codes)*, code something by sound *(phonological codes)*, or focus on the meaning of a stimuli *(semantic codes)*. For physical actions, such as learning sports or playing musical instruments, we code patterns of movement *(motor codes)*.

Realize that the form of a memory code often does not correspond to the form of the original stimulus. For example, as you read these words (visual stimuli) you are probably not storing images of the way the letters look. Rather, you are likely forming phonological codes (as you say the words silently to yourself) and semantic codes that represent their meaning (as you think about the material). Thus when people are presented with lists of words or letters and asked to recall them immediately, they often make phonetic errors. They might mistakenly recall a *V* as a *B* because of the similarity in how the letters sound (Conrad, 1964).

Capacity and Duration Short-term memory can hold only a limited amount of information at a time, as you may have observed if you've tried to memorize two or three different phone numbers at the same time. Depending on the stimulus, such as a series of unrelated numbers or letters, most people can hold no more than five to nine meaningful items in short-term memory, leading George Miller (1956) to set the capacity limit at "the magical number seven, plus or minus two." To demonstrate this, try administering the digit-span test in Table 7.1 to some people you know.

TABLE 7.1 Digit-Span Test

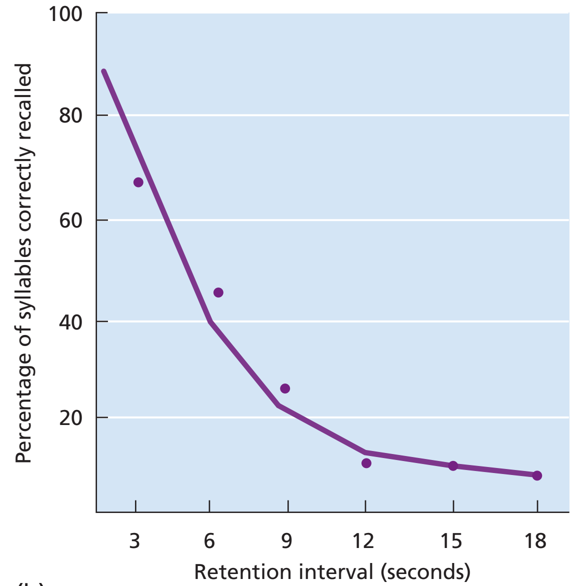
Directions: Starting with the top sequence, read these numbers at a steady rate of one per second. Immediately after saying the last number in each series, signal the person to recall the numbers in order. Most people can recall a maximum sequence of 5 to 9 digits.

8 3 5 2
4 3 9 3 1
7 1 4 9 3 7
5 4 6 9 2 3 6
1 5 2 4 8 5 8 4
9 3 2 6 5 8 2 1 4
6 8 1 3 1 9 4 7 3 5
4 2 4 6 9 5 2 1 7 4 3
3 7 9 8 4 6 1 7 2 4 9 5

2. Describe sensory memory. How long does information remain in iconic memory and how did Sperling determine this?

For more on iconic memory, see Interactive Segment 7.1.

(a)



(b)

FIGURE 7.5

(a) When you meet someone in a social situation, you can help yourself remember his or her name by repeating it. (b) Participants who were prevented from rehearsing three-letter syllables in working memory showed almost no recall of the letters within 18 seconds, illustrating the rapid forgetting of information in short-term memory.
SOURCE: Based on Peterson & Peterson, 1959.

8. 3. Discuss short-term memory and its limits. Contrast the concept of short-term memory with the working memory model.

If short-term memory capacity is so limited, how can we remember and understand sentences as we read? For a partial answer to this, read the following line of letters below (about one per second), then cover it up and write down as many letters as you can remember, in the order presented.

B I R C D E R Y K A E U Q S A S A W T I

Did you have trouble? Now reverse the letters, and write them down in order. Here are the 20 letters: "It was a squeaky red crib." No doubt, you find this task much easier. The limit on short-term storage capacity concerns the number of meaningful *units* that can be recalled, and the 20 letters have been combined into 6 meaningful units (words). *Combining individual items into larger units of meaning is called* **chunking,** and it can greatly aid recall.

Short-term memory is limited in duration as well as capacity. Have you ever been introduced to someone and then, moments later, realized that you've forgotten her or his name? Without rehearsal, information in working memory generally has a "shelf life" of up to 20 seconds (Figure 7.5; Peterson & Peterson, 1959). However, by rehearsing information—such as when you look up a telephone number and keep saying it to yourself while waiting to use a phone—we can extend its duration in short-term memory.

Putting Short-Term Memory "to Work" The original three-stage model viewed short-term memory primarily as a temporary holding station along the route from sensory to long-term memory. Information that remained in short-term memory long enough presumably was transferred into more permanent storage. Cognitive scientists now reject this view as too passive. Instead, they view short-term memory as **working memory**—a limited-capacity system that temporarily stores and processes information, (Baddeley, 2002). In other words, *working memory* is a "mental workspace" that not only stores information, but also actively manipulates it and supports other cognitive functions such as problem solving and planning. To illustrate, add the numbers 87 and 36 in your head. To enable you to solve this problem, your working memory must store the numbers, call up information from long-term memory on how to add, keep track of the interim steps (7 + 6 = 13, carry the 1), and coordinate all of these mental processes.

According to one influential model, working memory has several components (Baddeley & Hitch, 1974, 2000). For example, we temporarily store and process some information in an auditory component called the *phonological loop*, as occurs when you repeat to yourself the name of someone you have just met. Another component, the *visuo-spatial sketchpad*, temporarily stores and manipulates mental images and spatial information, as when forming a mental map of the route to the home of a new friend. In addition, a control process called the *central executive* directs the action. It decides how much attention to allocate to mental imagery and auditory rehearsal, calls up information from long-term memory, and integrates the input. Psychologists are also exploring other components of working memory (Baddeley, 2002).

Long-Term Memory

Long-term memory *is our vast library of more durable stored memories*. Perhaps there have been times in your life, such as periods of intensive study during final exams, when you have felt as if "the library is full," with no room for storing so much as one more new fact inside your brain. Yet as far as we know, long-term storage capacity essentially is unlimited, and once formed, a long-term memory can endure for up to a lifetime.

Are short-term and long-term memory really distinct? Case studies of amnesia victims like H. M. suggest so. If you told H. M. your name or some fact, he could remember it briefly but could not form a long-term memory of it. Experiments in which people with normal memory learn lists of words also support this distinction. Suppose that we present you with a series of 15 unrelated words, one word at a time. Immediately after seeing or hearing the last word, you are to recall as many words as you can, in any order you wish. As Figure 7.6 illustrates, most experiments find that words at the end and beginning of the list are the easiest to recall. This U-shaped pattern is called the **serial position effect,** *meaning that recall is influenced by a word's position in a series of items*. The serial position effect has two components: a *primacy effect*, reflecting the superior recall of early words, and a *recency effect*, representing the superior recall of the most recent words.

What causes the primacy effect? According to the three-stage model, as the first few words enter short-term memory, we can quickly rehearse them and transfer them into longer-term memory. However, as the list gets longer, short-term memory rapidly fills up and there are too many words to keep repeating before the next word arrives. Therefore, beyond the first few words, it is harder to rehearse the items and they are less likely to get transferred into long-term memory. If this hypothesis is correct, then the primacy effect should decrease if we can prevent people from rehearsing the early words, say by presenting the list at a faster rate. Indeed, this is what happens (Glanzer, 1972).

As for the recency effect, the last few words still linger in short-term memory and have the benefit of not being bumped out by new information. Thus if we try to recall the list immediately, all we have to do is "read out" the last words from short-term memory before they decay (i.e., fade away). In sum, according to the three-stage model, the primacy effect is due to the transfer of early words into long-term memory, whereas the recency effect is due to the continued presence of information in short-term memory.

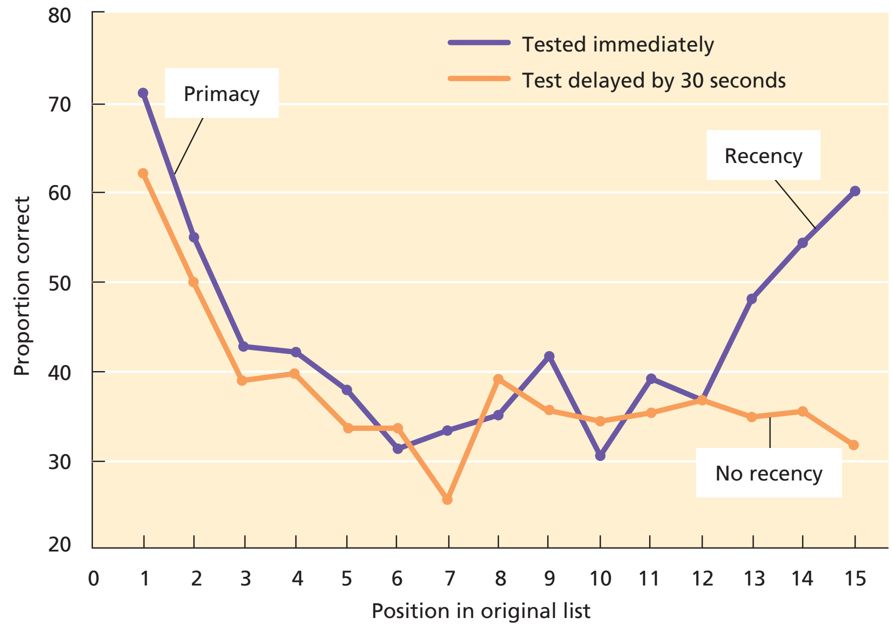


FIGURE 7.6

Immediate recall of word lists produces a serial position curve, where primacy and recency effects are both evident. However, even a short delay of 30 seconds in recall (during which rehearsal is prevented) eliminates the recency effect, indicating that the later items in the word list have disappeared from short-term memory.
SOURCE: Adapted from Glanzer & Cunitz, 1966.

If this explanation is correct, then we should be able to wipe out the recency effect—but not the primacy effect—by eliminating the last words from short-term memory. This happens when the recall test is delayed, even for as little as 15 to 30 seconds, *and* you are prevented from rehearsing the last words. To prevent rehearsal, we might briefly ask you to count a series of numbers immediately after presenting the last word (Glanzer & Cunitz, 1966; Postman & Phillips, 1965). Now by the time you try to recall the last words, they will have faded from short-term memory or been bumped out by the arithmetic task (6 . . . 7 . . . 8 . . . 9 . . .). Figure 7.6 shows that under delayed conditions, the recency effect disappears while the primacy effect remains.

Having examined some basic components of memory, let us now explore more fully how information is encoded, stored, and retrieved.

For more on working memory, see Interactive Segment 7.2.

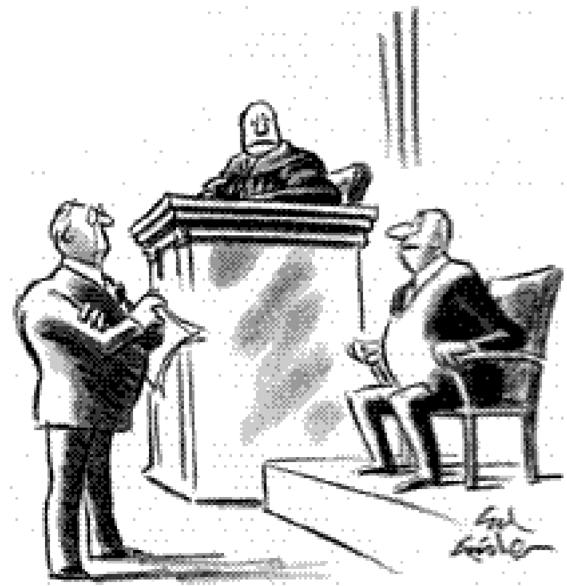
4. Describe long-term memory and its limits. Based on the three-stage model, why does the serial position effect occur?

Encoding: Entering Information

The holdings of your long-term memory, like those of a library, must be organized if they are to be available when you wish to retrieve them. The

FIGURE 7.7

Ineffective encoding can have practical as well as theoretical significance. © The New Yorker Collection 1983 Ed Fisher from cartoonbank.com. All rights reserved.



"The matters about which I'm being questioned, Your Honor, are all things I should have included in my long-term memory but which I mistakenly inserted in my short-term memory."

more effectively we encode material into long-term memory, the greater the likelihood of retrieving it (Figure 7.7).

Effortful and Automatic Processing

Think of the parade of information that you have to remember every day: names, meeting times, and mountains of schoolwork. Remembering it all involves *effortful processing,* encoding that is initiated intentionally and requires conscious attention (Hasher & Zacks, 1979). When you rehearse information, make lists, and take notes, you are engaging in effortful processing.

In contrast, have you ever been unable to answer an exam question and thought, "I should be able to answer this! I can even picture the diagram on the upper corner of the page!" In this case, you have apparently transferred incidental information about the diagram's location on the page (which you were not trying to learn) into your long-term memory through *automatic processing,* encoding that occurs without intention and requires minimal attention. Information about the frequency, spatial location, and sequence of events is often encoded automatically (Jimenez & Mendez, 2001).

5. Contrast automatic and effortful processing and discuss the levels of processing model.

Levels of Processing: When Deeper Is Better

Imagine that you are participating in a laboratory experiment and are about to be shown a list of words, one at a time. Each word will be followed by a question, and all you have to do is answer "yes" or "no." Here are three examples:

1. POTATO "Is the word in capital letters?"
2. HORSE "Does the word rhyme with course?"
3. TABLE "Does the word fit in the sentence, 'The man peeled the ________'?"

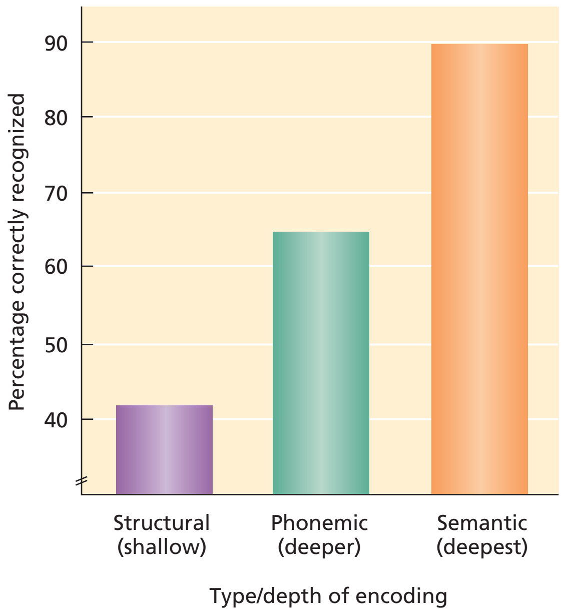
Each question requires effort but differs from the others in an important way. Question 1 requires superficial *structural encoding,* as you only have to notice how the word looks. Question 2 requires a little more effort. You must engage in *phonological* (also called *phonemic*) *encoding* by sounding out the word to yourself and then judging whether it matches the sound of another word. Question 3 requires *semantic encoding* because you must pay attention to what the word means.

In this experiment, every word you will be shown will be followed by a question that requires either structural, phonological, or semantic encoding. Unexpectedly, you will then be given a memory test in which you will be shown a list of words and asked to identify which words were presented earlier. Which group of words will you recognize most easily? Those processed structurally, phonologically, or semantically?

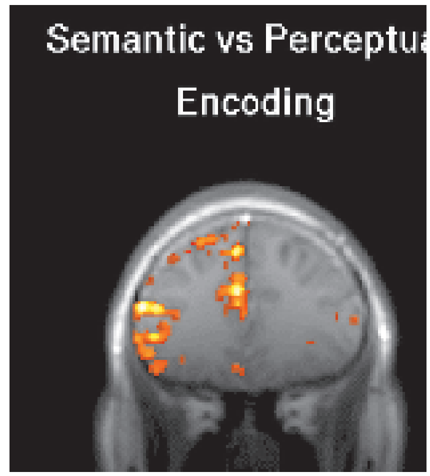
According to the concept of **levels of processing**, *the more deeply we process information, the better we will remember it* (Craik & Lockhart, 1972). Thus you should best remember those words that you processed semantically. Semantic encoding involves the deepest processing because it requires us to focus on the meaning of information. Merely perceiving the structural properties of the words (e.g., capitalized versus lowercase) involves shallow processing, and phonemically encoding words is intermediate. Figure 7.8a shows that the semantically encoded words were best remembered (Craik & Tulving, 1975). Moreover, as Figure 7.8b shows, deeper processing of words produces greater neural activity in several areas of the cerebral cortex (Walla et al., 2001).

Exposure and Rehearsal

Years ago one of our students sought advice after failing an exam. He said that he had been to all the lectures and read each chapter three times. Yet not a word in his textbook had been underlined or highlighted. When asked whether he took notes as he read the text or paused to reflect on the information, he said no. Instead, he read and reread each chapter quickly, much like a novel, and assumed that the information would somehow sink in.



(a)



(b)

FIGURE 7.8

(a) Depth of processing facilitates memory. Participants were shown words and asked questions that required (1) superficial structural processing, (2) somewhat deeper phonemic processing, or (3) deeper semantic processing of each word. Depth of processing increased later recognition of the words in a larger list. SOURCE: Data from Craik & Tulving, 1975. *(b) Four of the participants in this experiment performed shallow (i.e., perceptual/structural) encoding and deep (semantic) encoding tasks while undergoing functional magnetic resonance imaging (fMRI). Activity in a section of their prefrontal cortex was imaged every 1.5 seconds, yielding a total of 224 images per participant. The results, shown here for one participant, revealed that semantic encoding was accompanied by greater neural activity in specific regions of the left prefrontal cortex.* Photo courtesy of John Gabrieli.

Unfortunately, mere exposure to a stimulus without focusing on it represents shallow processing. To demonstrate this for yourself, try drawing from memory a picture of the smallest-denomination coin in your country (e.g., a U.S. penny), accurately locating all the markings. Few people can do this. Even thousands of shallow exposures to a stimulus do not guarantee long-term retention.

Rehearsal is a step beyond mere exposure; when we rehearse information, we are thinking about it. But not all rehearsal is created equal. Have you ever seen a play and been amazed at the way professional actors flawlessly recall volumes of material in front of live audiences? You may picture the actors reading the script and saying the words over and over, day after day, until they've memorized their lines. This approach, called **maintenance rehearsal,** *involves simple, rote repetition,* and some students rely on it to learn their course material.

Maintenance rehearsal keeps information active in short-term memory, as when someone tells you a phone number and you repeat it to yourself as you place the call. It can also help transfer information into long-term memory (Wixted, 1991). However, rote memorization usually is not an optimal method for bringing about long-term transfer.

What, then, is the best way to bring material—such as an actor's script or information in a textbook—into long-term memory? It may surprise you to know that professional actors begin not by memorizing but by studying the script in great depth, trying to get into the mindset of their characters (Figure 7.9). Based on detailed research, psychologists Tony and Helga Noice (2002a) note that actors, "before they gave any thought to memorization, stressed the notion of understanding the ideas behind the utterances, and the reasons the characters used those words to express those ideas." The techniques actors use are examples of **elaborative rehearsal**, *which involves focusing on the meaning of information or expanding (i.e., elaborating) on it in some way.*

If your study habits include (1) organizing and trying to understand the material rather than just memorizing it, (2) thinking about how it applies to your own life, and (3) relating it to concepts or examples you already know, then you are using elaboration. According to Craik and

FIGURE 7.9

Professional stage actors use elaborative rehearsal extensively to learn their roles and numerous lines. They employ many of the memory techniques discussed in the "Applying Psychological Science" feature on page 139.

SOURCE: Noice & Noice, 2002a.

6. Contrast maintenance and elaborative rehearsal. Describe ways to use organization and imagery to enhance encoding.

Lockhart (1972), elaborative rehearsal involves deeper processing than maintenance rehearsal, and experiments show that it is more effective in transferring information into long-term memory (Benjamin & Bjork, 2000).

Organization and Imagery

J. C. is an awe-inspiring restaurant waiter. Perhaps you would like a filet mignon, medium-rare, a baked potato, and Thousand Island dressing on your salad? Whatever you order, it represents only one of over 500 options (7 entrees × 5 serving temperatures × 3 side dishes × 5 salad dressings) available at the restaurant where J. C. works. Yet you and 20 or so of your best friends can place your selections with J. C., and he will remember them perfectly without writing them down.

Psychologists K. Anders Ericsson and Peter Polson (1988), who studied J. C., found that he invented an organizational scheme to aid his memory. He divided customers' orders into four categories (entree, temperature, side dish, dressing) and then used a different system to encode the orders in each category. For example, he encoded dressings by their initial letter, so orders of Thousand Island, oil and vinegar, blue cheese, and oil and vinegar would become *TOBO*. Organizational schemes are an excellent way to enhance memory. They can enhance the meaningfulness of information and also serve as cues that help trigger our memory, just as the word *TOBO* jogs J. C.'s memory of the four orders of salad.

Hierarchies and Chunking Organizing material in a *hierarchy* takes advantage of the principle that memory is enhanced by associations between concepts (Bower, et al., 1969). A logical hierarchy enhances our *understanding* of how individual items are related, and as we proceed from top to bottom, each category serves as a cue that triggers our memory for the items below it. Because hierarchies have a visual organization, imagery can be used as a supplemental memory code. The hierarchy in Figure 7.10, for example, may help you remember some concepts about encoding.

As we discussed earlier, chunking refers to combining individual items into a larger unit of meaning. To refresh your memory, read the line of letters below to yourself (about one per second) and try to recall as many as you can, in the same sequence.

I R S Y M C A I B M K G B F B I

If you recalled 5 to 9 letters in order, you did well. Now let's reorganize these 16 letters into

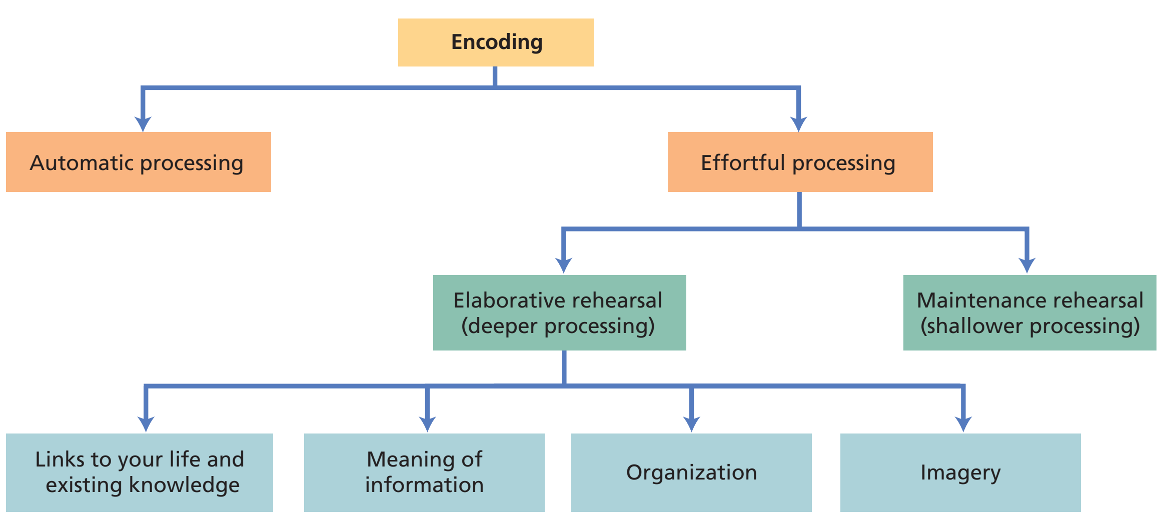


FIGURE 7.10

Placing information into a meaningful hierarchy enhances encoding and memory. This hierarchy could be developed further by adding a fifth level of boxes under "Organization" labeled Hierarchies, Chunking, Acronyms, *and* Rhymes. *A box labeled* Method of Loci *could be added under "Imagery," although it also organizes information.*

5 larger, more meaningful chunks: IRS, YMCA, IBM, KGB, and FBI. These chunks are easier to rehearse, keep active in working memory, and transfer into long-term memory. When learning a new telephone number (e.g., 206-543-2640), you probably encode it in chunks.

For more on chunking in memory, see Interactive Segment 7.3.

Visual Imagery How many windows are there in your home? What did your bedroom look like during your high school years? To answer these questions, you might try to construct a series of mental images in your working memory, based on information that you draw out of long-term memory.

Allan Paivio (1969) proposes that information is stored in long-term memory in two forms: verbal codes and visual codes. According to his **dual coding theory,** *encoding information using both verbal and visual codes enhances memory*, because the odds improve that at least one of the codes will be available later to support recall. Dual coding, however, is harder to use with some types of stimuli than others. Try to construct a mental image of (1) a fire truck and (2) a lightbulb. Now construct an image of (1) jealousy and (2) knowledge. You probably found the second task more difficult, because those words represent abstract concepts rather than concrete objects (Paivio et al., 2000).

Memory improvement books often recommend using imagery to dual-code information, and research supports this approach. The ancient Greeks developed the **method of loci** (*loci* is Latin for "places"), *a mnemonic device that associates information with mental images of physical locations*. To use this well-known technique, imagine a physical environment with a sequence of distinct landmarks, such as the rooms in a house or places on your campus. Next, to remember a list of items, take an imaginary stroll through this environment and form an image linking each place with an item. It may be challenging to use this imagery technique to learn abstract concepts, but here's one example: To remember the three major components of working memory, you might imagine walking into the president's office at your college *(central executive)*, then watching a band rehearsal in your gym *(phonological loop)*, and finally visiting an art class *(visuo-spatial sketchpad)*. Many studies support the method of loci's effectiveness (Wang & Thomas, 2000).

Other Mnemonic Devices The term *mnemonics* (nee-MON-iks) refers to the art of improving memory, and a **mnemonic device** *is a memory aid*. Mnemonic devices reorganize information into more meaningful units and provide extra cues to help retrieve information from long-term memory. Hierarchies, chunking, visual imagery, and the method of loci are mnemonic devices. So are *acronyms*, which combine one or more letters (usually the first letter) from each piece of information you wish to remember. For example, many students learn the acronyms HOMES and ROY G. BIV to help remember the names of the five Great Lakes of North America (Huron, Ontario, Michigan, Erie, Superior) and the hues in the visible spectrum—the "colors of the rainbow" (red, orange, yellow, green, blue, indigo, violet).

Even putting information in a rhyme may help you remember it. Some of our own students use this technique. Advertisers also employ this principle when they include rhyming phrases or jingles in their messages. In one experiment, college students and other adults listened to a 10-minute radio program into which researchers had inserted an advertisement for a fictitious mouth rinse (Cavoloss). The advertisement either contained a rhyme ("Toss the floss, use Cavoloss") or presented the same information without a rhyme. Tested 1 week later, participants exposed to the rhyme remembered more product information and showed better brand name recall (Smith & Phillips, 2001).

How Prior Knowledge Shapes Encoding

Can you recall the paragraph you just read word for word? Typically, when we read, listen to someone speak, or experience some event, we do not precisely encode every word, sentence, or moment. Rather, we usually encode the gist—the general theme (e.g., "rhymes can enhance memory")—of that information or event.

Schemas: Our Mental Organizers The themes that we extract from events and encode into memory are often organized around schemas. A **schema** (plural: *schemas*, or *schemata*) *is a "mental framework"—an organized pattern of thought—about some aspect of the world* (Bartlett, 1932; Koriat et al., 2000). For example, the concepts "dog," "shopping," and "love" serve as schemas that help you organize your world. To see more clearly what a schema is and how it can influence the way we encode material in memory, read the following paragraph.

> The procedure is actually quite simple. First you arrange things into different groups. Of course, one pile may be sufficient depending on how much there is to do. If you have to go somewhere else due to lack of facilities, that is the next step; otherwise you are pretty

> well set. It is important not to overdo things. That is, it is better to do too few things at once than too many. In the short run this might not seem important, but complications can easily arise. A mistake can be expensive as well. . . . After the procedure is completed, one arranges the materials into different groups again. Then they can be put into their appropriate places. Eventually they will be used once more, and the whole cycle will have to be repeated. However, that is part of life. (Bransford & Johnson, 1972, p. 722)

Asked to recall the details of the preceding paragraph, you would probably have trouble. However, suppose we tell you that the paragraph is about a common activity: washing clothes. Now if you read the paragraph again, you will find that the abstract and seemingly unrelated details suddenly make sense. Your schema—your mental framework for "washing clothes"—helps you organize and interpret these details and thus remember more of them.

7. How do schemas affect encoding? What role do schemas and mnemonic devies play in expertise and exceptional memory?

Schemas and Expert Knowledge When people who have never learned to read music look at a musical score, they see an uninterpretable mass of information. In contrast, musicians see organized patterns that they can easily encode. In music as in other fields, from computer programming to rock climbing, acquiring *expert knowledge* can be viewed as a process of developing schemas—mental frameworks—that help encode information into meaningful patterns (Boschker et al., 2002).

William Chase and Herbert Simon (1973) demonstrated the relation between expertise, schemas, and encoding in an intriguing study. Three chess players—an expert ("master"), an intermediate player, and a beginner—were allowed 5 seconds to look at a chess board containing about 25 pieces. Then they looked away and, on an empty board, attempted to reconstruct the placement of the pieces from memory. This was repeated over several trials, each with a different arrangement of pieces. On some trials, the chess pieces were arranged in *meaningful positions* that actually might occur in game situations. With only a 5-second glance, the expert typically recalled 16 pieces, the intermediate player 8, and the novice only 4. What may surprise you is that when the pieces were in *random positions,* there was no difference in recall between the three players. They each did poorly, accurately recalling only 2 or 3 pieces.

How would you explain these results? We have to reject the conclusion that the expert had better overall memory than the other players, because he performed no better than they did with the random arrangements. But the concepts of schemas and chunking do explain the findings (Gobet & Simon, 2000). When the chess pieces were arranged in meaningful positions, the expert could apply well-developed schemas to recognize patterns and group pieces together. For example, he would treat as a unit all pieces that were positioned to attack the king. The intermediate player and especially the novice, who did not have well-developed chess schemas, could not construct the chunks and had to try to memorize the position of each piece. However, when the pieces were not in positions that would occur in a real game, they were no more meaningful to the expert than to the other players. When that happened, the expert lost the advantage of schemas and had to approach the task on a piece-by-piece basis just as the other players did. Similarly, football coaches show much better recall than novices do after looking at diagrams of football plays (patterns of X's and O's), but only when the plays are logical (Figure 7.11).

You may not be an advanced chess player or coach, but you have years of experience about how various aspects of the world work. As the clothes-washing example illustrates, your own "expert schemas" influence what you encode and remember.

Encoding and Exceptional Memory

After witnessing an impressive memory feat—a waiter's remembering 20 dinner orders without writing them down or Rajan Mahadevan's recalling 31,811 digits of pi—it's tempting to assume that the person has an innate, so-called "photographic memory." But K. Anders Ericsson and William Chase (1982) argue that such exceptional memory is a highly learned skill that can be explained by three basic principles: (1) prior knowledge and extensive practice, (2) meaningful associations, and (3) efficient storage and retrieval structures.

They tested their hypothesis by examining whether S. F., a college student with average memory skills, could develop exceptional memory (Ericsson et al., 1980). S. F. practiced digit-span tasks for 1 hour a day, 3 to 5 days a week, for 20 months. If he correctly recalled a string of digits (one digit was presented per second), the next string was increased by a digit. After an error, the next sequence was decreased by a digit. S. F.'s digit-span performance improved steadily, and after 190 hours of practice, he could listen to a string of 80 digits and recall them perfectly.

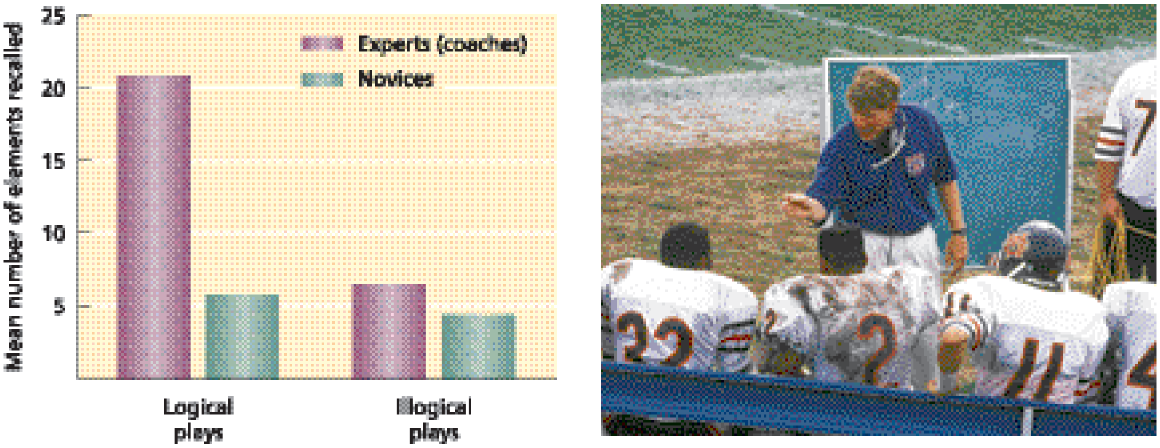


FIGURE 7.11

Diagrams of football plays were shown to football coaches (experts) and to people who had played football but were not coaches (novices). Given 5 seconds to see each play, coaches displayed excellent memory—but only when the plays were logical. Their well-developed football schemas were of little use when the patterns of Xs and Os were illogical. The findings are very similar to those obtained when expert and novice chess players tried to reproduce meaningful and random arrangements of chess pieces. SOURCE: Data from Garland & Barry, 1991.

How did S. F. do it? On his own, he learned to use chunking, associations, and hierarchical organization to rapidly transfer digits into long-term memory. S. F. was an experienced runner, and he grouped digits into chunks that he associated with running times, ages, or dates. Thus 3492 became become “3 minutes and 49.2 seconds, near world-record time for running a mile”; 893 became “89.3 years old, a very old person”; and 1944 became “near the end of World War II.” As digit strings became longer, S. F. used hierarchical organization to arrange individual chunks into larger groups.

A **mnemonist** (or **memorist**) *is a person who displays extraodinary memory skills*. Studies reveal that like S. F., mnemonists take advantage of basic memory principles. They often chunk information into larger units and combine smaller chunks into larger ones. Many elaborate on the material by associating chunks with other information, as S. F. did when he linked chunks to running times, ages, and dates. Many mnemonists create visual images or stories to help them encode information; they may also combine several techniques.

How, then, did Rajan learn 31,811 digits of pi? Rajan said that he did not have a photographic memory, and Richard Thompson and coworkers (1993), who studied Rajan intensively, agreed. Instead, they found that Rajan used chunking; the mathematical tables of pi that he studied grouped digits in chunks of 10, so Rajan did the same. But, surprisingly, Rajan did not associate the chunks with meaningful material. Rather, beyond basic chunking, Rajan relied primarily on the brute force of rote memorization and extensive practice. How much practice? Thompson and coworkers estimated that it took Rajan over a year to learn the digits of pi.

Realize that just because rote memorization can transfer information into long-term memory doesn’t mean that it’s the best way. Mnemonists (including the person who broke Rajan’s record by recalling 40,000 digits of pi) often use elaborative rehearsal to achieve their amazing feats. More importantly, rote memorization is better suited to learning a string of numbers than to learning material that has meaning. When Rajan applied his rote strategy to memory tasks that involved meaningful stimuli (e.g., written stories, complex visual figures), he performed more poorly or no better than college students in a control group.

Should we accept the conclusion that exceptional memory is a learned skill? After thousands of hours of practice using effective encoding techniques, could the average person really remember 30,000 to 40,000 digits of pi? Thompson and coworkers (1993) believe that in memory, as in sports and music, endless skilled practice will not enable most people to rise to the top unless they also have the requisite ability. Yet Ericsson and coworkers (1993) disagree, arguing that “many characteristics once believed to reflect innate talent are actually the result of intense practice” (p. 363). This debate extends to cases of *savants*, people with mental disabilities who display exceptional memory for particular tasks. Some savants

For more on mnemonic strategies in memory, see Video Clip 7.1.

can reproduce complex musical pieces or a highly detailed drawings after hearing or seeing them only once, but researchers disagree as to whether this reflects natural ability or a highly practiced skill (Winner, 2000).

What Do You Think?

WOULD PERFECT MEMORY BE A GIFT OR A CURSE?

If you could have a perfect memory, would you want it? What might be the drawbacks? Think about it, then see page 140.

Storage: Retaining Information

Think for a moment about the incredible wealth of information that you can recall at a moment's notice. With little effort, you can probably remember the name of the capital of Russia, how to multiply 10 times 25, the flavor of your favorite ice cream, and how you spent your most recent vacation. This ability to rapidly access diverse facts, concepts, and experiences has influenced many cognitive models of how information is stored and organized in memory.

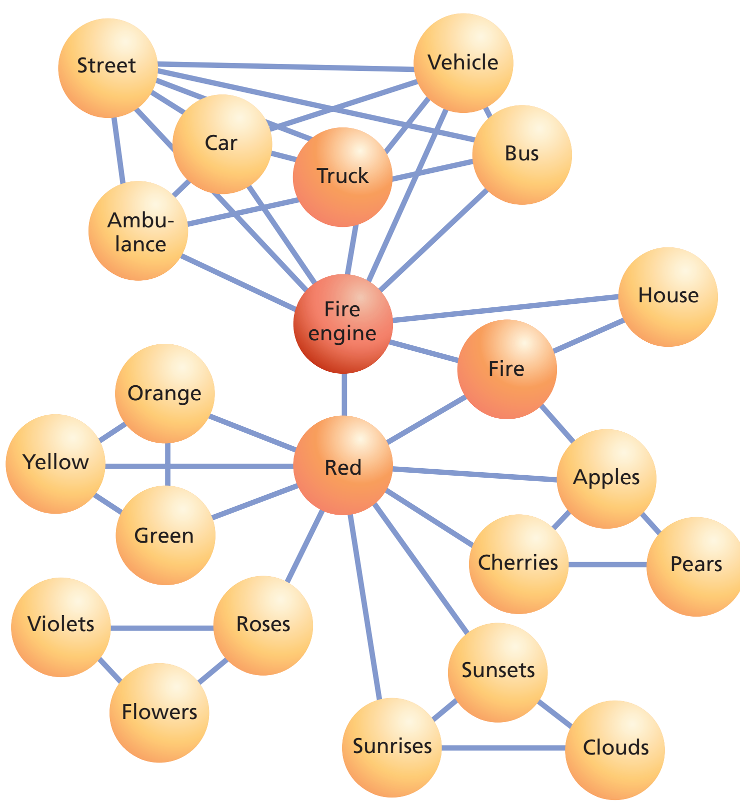


FIGURE 7.12

A network of concepts in semantic memory. The lines in the semantic network represent associations between concepts, with shorter lines indicating stronger associations. SOURCE: Adapted from Collins & Loftus, 1975.

Memory as a Network

We noted that memory is enhanced by elaborative rehearsal, which involves forming associations between new information and other items already in memory. The general principle that memory involves associations goes to the heart of the *network* approach.

Associative Networks One group of theories proposes that memory can be represented as an **associative network,** *a massive network of associated ideas and concepts* (Collins & Loftus, 1975). Figure 7.12 shows what a tiny portion of such a network might be like. In this network, each concept or unit of information—"fire engine," "red," and so on—is represented by a *node* somewhat akin to each knot in a huge fishing net. The lines in this network represent associations between concepts, with shorter lines indicating stronger associations. For simplicity, Figure 7.12 shows only a few connections extending from each node, but there could be hundreds or more. Notice that items within the same category—types of flowers, types of fruits, colors, and so on—generally have the strongest associations and therefore tend to be clustered closer together. In essence, an associative network is a type of schema; it is a mental framework that represents how we have organized information and how we understand the world (Roediger & McDermott, 2000).

Alan Collins and Elizabeth Loftus (1975) theorize that when people think about a concept, such as "fire engine," there is a *spreading activation* of related concepts throughout the network. For example, when you think about a "fire engine" related concepts such as "truck," "fire," and "red" should be partially activated as well. The term **priming** *refers to the activation of one concept (or one unit of information) by another*. Thus "fire engine" primes the node for "red," making it more likely that our memory for this color will be accessed (Chwilla & Kolk, 2002).

The notion that memory stores information in an associative network also provides one possible explanation for why hints and mnemonic devices help stimulate our recall (Reisberg, 1997). For example, when you hear "Name the colors of the rainbow," the nodes for "color" and "rainbow" jointly activate the node for "ROY G. BIV," which in turn primes your recall for "red," "orange," and so forth.

Neural Networks The neural network approach also can explain why spreading activation and priming occur, but it does so using a different model of memory (Chappell & Humphreys, 1994). A neural network has nodes that are linked to each other, but these nodes are physical in nature and do not contain individual units of information. There is no single node for "red," no single node for "fire engine," and so on. Instead, each node is more like a small information-processing unit. As an analogy, some proponents would say, think of each neuron in your brain as a node. A neuron processes inputs and sends outputs to other neurons, but as far as we know, the concepts of "red" and "fire engine," or your mental image of an elephant, are not stored within any single neuron.

Where, then, is a concept such as "red" stored? In a **neural network,** *each item in memory is represented by a particular pattern or set of nodes that becomes activated simultaneously*. When node 4 is activated simultaneously (i.e., in parallel) with nodes 9 and 42, the concept "red" comes to mind. But when node 4 is simultaneously activated with nodes 75 and 901, another concept enters our thoughts. As we look across the entire neural network, various nodes distributed throughout the brain fire in parallel at each instant and spread their activation to other nodes. In this manner, certain nodes prime other nodes, concepts and information are retrieved from memory, and thoughts arise. For this reason, neural network models are often called *parallel distributed processing models*, and scientists in many fields have become increasingly interested in them in recent years (Tryon, 2002).

8. Contrast associative and neural network models of memory, and explain priming.

Types of Long-Term Memory

Think back for a moment to the nature of H. M.'s amnesia. Since his brain operation, H. M. has been unable to consciously recall new facts or personal experiences once they leave his short-term memory. Each time he meets you he will believe it is the first time. Yet with practice, H. M. has learned new tasks even though he will never remember having seen them before (Milner, 1965).

Based on research with amnesia patients, brain-imaging studies, and animal experiments, many scientists believe that we possess several long-term memory systems that interact with one another (Nyberg et al., 2002; Tulving, 2002). This view is consistent with the concept, described in Chapter 5, that the mind involves distinct yet interrelated modules.

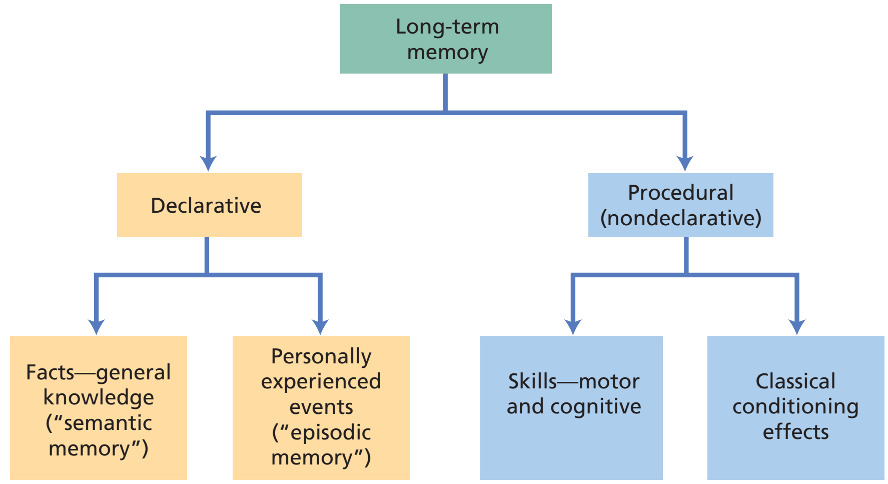


FIGURE 7.13

Some theorists propose that we have separate but interacting declarative and procedural memory systems. Episodic and semantic memories are declarative; their contents can be verbalized. Procedural memory is nondeclarative; its contents cannot readily be verbalized.

Declarative and Procedural Memory **Declarative memory** *involves factual knowledge,* and includes two subcategories (Figure 7.13). **Episodic memory** *is our store of knowledge concerning personal experiences*: when, where, and what happened in the *episodes* of our lives. Your recollections of childhood friends, how you spent last summer, and what you ate this morning represent episodic memories. **Semantic memory** *represents general factual knowledge about the world and language*, including memory for words and concepts. You know that Mount Everest is the world's tallest peak and that $e = mc^2$. Episodic and semantic memories are called *declarative* because to demonstrate our knowledge, we typically have to "declare it"—we tell other people what we know.

H. M.'s brain damage severely impaired both components of his declarative memory. Not only was he unable to remember new personal experiences, he also could not remember new general acts. For example, H. M. retained good memory for words that he had learned growing up (Kensinger et al., 2001). Yet no matter how many times he was told their definition, he could not remember the meaning of new words (e.g., *xerox*, *biodegradable*) that entered the English language in the years after his operation. In contrast, some brain-injured children with amnesia cannot remember their daily personal experiences but can indeed form memories for general factual knowledge, enabling them to learn language and attend mainstream schools (Vargha-Khadem et al., 1997).

Procedural (nondeclarative) memory *is reflected in skills and actions* (Gupta & Cohen, 2002). One component of procedural memory consists of skills that are expressed by "doing things" in particular situations, such as typing, riding a bicycle, or playing a musical instrument. Classically conditioned responses also reflect procedural memory. After a tone was repeatedly paired with a puff of air blown toward H. M.'s eye, he began to blink involuntarily to the tone alone (Woodruff-Pak, 1993). Although H. M. could not consciously remember undergoing this procedure (i.e., he did not form a declarative memory), his brain stored a memory for the tone–air puff association, and thus he blinked when subsequently exposed to the tone alone (i.e., he formed a procedural memory).

Explicit and Implicit Memory Many researchers distinguish between explicit and implicit memory (Schacter & Badgaiyan, 2001). **Explicit memory** *involves conscious or intentional memory retrieval, as when you consciously recognize or recall something. Recognition* requires us to decide whether a stimulus is familiar, as when an eyewitness is asked to pick out a suspect from a police lineup or when students take multiple-choice tests. In recognition tasks, the "target" stimuli (possible suspects or answers) are provided to you. *Recall* involves spontaneous memory retrieval, in the sense that you must retrieve the target stimuli or information on your own. This occurs when you are briefly shown a list of words and then asked to recall them. With *cued recall,* hints are given to stimulate memory. If you cannot recall the word *hat* from the list, we might say, "It rhymes with 'bat.'" As a student, you are no doubt familiar with test items that involve recall or cued recall, such as essay, short-answer, and fill-in-the-blank questions.

9. Contrast and illustrate declarative versus procedural memory, and explicit versus implicit memory.

Implicit memory *occurs when memory influences our behavior without conscious awareness.* H. M. was able to remember how to perform the mirror-tracing task, although he had no conscious awareness of having learned it. His memory for the task (in this case, procedural memory) was implicit. In Chapter 5 we encountered another amnesia patient, whose hand Edouard Claparède (1911) intentionally pricked with a pin during a handshake. Shortly thereafter she could not consciously recall this incident, but despite her amnesia, she showed implicit memory of their encounter by withdrawing her hand when Claparède offered to shake it again.

In less dramatic ways, each of us demonstrates memory without conscious awareness. Riding a bicycle, driving, or performing any well-learned skill provides a common example. Bicycling to class, you may be consciously thinking about an upcoming exam while your implicit, procedural memory enables you to keep pedaling and maintain your balance.

Consider another example of implicit memory. Suppose that as part of an experiment you read a list of words (one word per second) that includes *kitchen*, *moon*, and *defend*. Days, weeks, or even a year later, you participate in another, seemingly unrelated study. The experimenter rapidly shows you many word stems, some of which might be *KIT*—, *MO*—, and *DE*—, and asks you to complete each stem to form a word. You are not aware that this is a memory test, but compared with people not given the original list of words, you will be more likely to complete the stems with words on the original list (e.g., *MOon*, rather than *MOther* or *MOney*). This represents one of many types of *priming tasks*: The word stems (*KIT, MO, DE*) have activated, or "primed," your stored mental representations of the original complete words. This suggests that information from the original list is still in your memory and is implicitly influencing your behavior even though you may have no explicit, conscious recall of the original words (Schacter, 1992).

Retrieval: Accessing Information

Storing information is useless without the ability to retrieve it. Imagine having to search for a specific title in a library where the books have been shelved without catalog (i.e., call) numbers. In contrast, if we have a catalog number and the book is shelved correctly, we can easily find it.

A retrieval cue—like a library catalog number—*is any stimulus, whether internal or external, that stimulates the activation of information stored in long-term memory*. If I ask you, "Have you seen Sonia today?" the word Sonia is intended to serve as a retrieval cue. Likewise, seeing a yearbook picture of a high school classmate can act as a retrieval cue that triggers memories of that person. Priming is another example of how a retrieval cue ("fire engine," "MO—") can trigger associated elements ("red," "MOon") in memory, presumably via a process of spreading activation (Chwilla & Kolk, 2002).

The Value of Multiple Cues

Experiments by Timo Mäntylä (1986) vividly show the value of having multiple retrieval cues.

In one, Swedish college students were presented with a list of 504 words. Some students were asked to think of and write down one association for each word, while others produced three associations per word. To illustrate, what three words come to your mind when I say "banana"? Perhaps you might think of "peel," "fruit," and "ice cream."

The students had no idea that their memory would be tested, and after finishing the association task they were given an unexpected recall test for 252 of the original words. For some words, students were first shown the one or three associations they had just generated. As a control, for other words they were first shown one or three associations *another* participant had generated. Then they tried to recall the original word.

The results were remarkable. When the associations (i.e., retrieval cues) were self-generated, students shown one cue recalled 61 percent of the words and those shown three cues recalled 91 percent. In contrast, when students were shown cues that someone else had generated, recall with one cue dropped to 11 percent and with three cues to 55 percent. Finally, when given another surprise recall test 1 week later on the remaining 252 words, students still remembered 65 percent of the words when they were first provided with three self-generated retrieval cues—far better than any other condition.

Across many experiments, Mäntylä consistently found that having multiple, self-generated retrieval cues maximized recall. Why might this be? On the encoding side, generating our own associations involves deeper, more elaborative processing than does being presented with associations generated by someone else. Similarly, generating three associations involves deeper processing than thinking of only one. On the retrieval side, these self-generated associations become cues that have personal meaning. With multiple cues, if one fails, another may activate the memory. The implication for studying academic material is clear. Think about the material you are studying, and draw one or (preferably) more links to ideas, knowledge, or experiences that have meaning for you.

The Value of Distinctiveness

To demonstrate a simple point, here is a brief self-test. A list of words appears below. Say each word to yourself (one per second), then when you see the word *WRITE,* look away and write down as many words as you can recall, in any order. Here's the list:

sparrow, eagle, nest, owl, feather, goose, crow, tomato, rooster, fly, robin, parrot, chirp, hawk, pigeon, WRITE.

If you are like most of our own students, you probably recalled *tomato* even though it appeared in the middle of the list. In this list, *tomato* is distinctive. It's a vegetable, and thus it stands out from the crowd (or at least, from the flock). It catches our attention. In general, distinctive stimuli are better remembered than nondistinctive ones (Ghetti et al., 2002).

In school, when all the material "starts looking alike," you can make it more distinctive by associating it with other information that is personally meaningful to you. According to Mäntylä (1986), this is one reason why students who generated their own three-word associations remembered almost all of the original 500 words. The associations formed a distinctive set of cues.

10. How do retrieval cues assist memory? What is the benefit of having multiple, self-generated, and distinctive cues?

Distinctive events stand a greater chance of etching long-term memories that seem vivid and clear. In one study, college students listed their three clearest memories (Rubin & Kozin, 1984). Distinctive events such as weddings, romantic encounters, births and deaths, vacations, and accidents were among the most frequently recalled. In another study, college students watched a videotape of a guest lecturer who engaged in some distinctive, atypical behaviors (e.g., ate potato chips, burped) and some typical ones (e.g., sat down, took off jacket). A week later, students were given a list of behaviors and asked to identify which ones had taken place during that lecture. Half of the listed items actually appeared in the videotape, and half did not (e.g., zipped up pants, erased board). Students correctly identified about 80 percent of the behaviors that had occurred, but they were more likely to report being able to "mentally relive"—to have a clear image of—the distinctive events (Neuschatz et al., 2002).

Of course, just because a memory seems vivid or we are confident of it doesn't guarantee its accuracy. Students falsely "recognized" 45 percent of the typical behaviors and 25 percent of the distinctive behaviors that actually had never occurred. In most cases, they felt sure that the behavior had taken place, although they said they couldn't consciously remember it. But for a third of these false recognitions, students said they had a clear memory of a nonexistent event.

Do similar errors occur when we retrieve memories of even more distinctive, dramatic real-world events—events that we can "remember like it was yesterday"? Let's take a look "beneath the surface."

Beneath the Surface

DO WE REALLY "REMEMBER IT LIKE IT WAS YESTERDAY"?

Can you picture the tragic moment on September 11, 2001, when you first heard or saw that jetliners had crashed into the World Trade Center and the Pentagon (Figure 7.14)? Do you recall what you were doing when you learned that Princess Diana had been killed in a car crash? Your authors, like others of our generation, can vividly recall the moment over 40 years ago when we heard that President John F. Kennedy had been assassinated.

Flashbulb memories *are recollections that seem so vivid, so clear, that we can picture them as if they were a "snapshot" of a moment in time*. They are most likely to occur for distinctive, positive or negative events that evoke strong emotional reactions and which are repeatedly recalled in conversations with other people (Brown & Kulik, 1977).

Flashbulb Memories: Fogging up the Picture?

Because flashbulb memories seem vivid and are easily recalled, we often feel confident of their accuracy. But are they accurate? In 1986, the space shuttle Challenger exploded shortly after takeoff, killing all on board. It was a horrific event, replayed on TV worldwide, and the American public was shocked. The next day, Ulric Neisser and Nicole Harsch (1993) asked college students to describe how they learned of the disaster, where they were, who they were with, and so on. Reinterviewed 3 years later, about half of the students remembered some details correctly but recalled other details inaccurately. One fourth of the students completely misremembered all the major details and were astonished over how inaccurate their memories were after reading their original descriptions.

For a captivated public that followed the 1995 O. J. Simpson murder trial, the jury's verdict of "not guilty" seemed to be an unforgettable moment. Was it? Three days later researchers asked college undergraduates how, when, with whom, and where they had learned of the verdict (Schmolck et al., 2000). Students reported whether they agreed with the verdict and how emotional they felt about it. When some students' memory was retested 15 months later, only 10 percent made major mistakes in recalling the event. Over time, however, the flashbulb seemed to fade. Among other students retested 32 months after

FIGURE 7.14

A flashbulb memory is a recollection that seems so vivid and clear that we can picture it as if it were a "snapshot" of a moment in time.

the verdict, 43 percent misremembered major details. Here's how one student's memory changed:

> [3 days after the verdict] I was in the Commuter Lounge at Revelle [College] and saw it on T.V. . . . more and more people came into the room. We kept having to turn up the volume, but it was kind of cool.
>
> [32 months after the verdict] I first heard it while I was watching T.V. At home in my living room. My sister and father were with me . . . eating and watching (p. 41).

Memory accuracy was not related to whether students had originally agreed or disagreed with the verdict; instead, those who reported a stronger emotional reaction in 1995 displayed better memory 32 months later.

Confidence and Memory Accuracy

If people are highly confident in their memory, is it likely to be accurate? Three years after the O. J. Simpson verdict, almost all the students who had accurate memories displayed high confidence. But one of the most striking findings was that among students with grossly inaccurate recall, 61 percent also were highly confident of their memories.

In the 7th week after the 9/11 terrorist attacks, psychologist Kathy Pezdek (2002) asked 569 students attending college in New York City (Manhattan), southern California, and Hawaii to complete a memory questionnaire. One item asked, "On September 11, did you see the videotape on television of the first plane striking the first tower." Overall, 73 percent of the students said yes. Yet this was impossible, because the videotape of the first plane crashing was not broadcast until September 12. Moreover, students who incorrectly responded yes were more confident in their memory than the students who correctly said no! Similarly, after Princess Diana died, a study in England found that 44 percent of participants said that they had seen a videotape on the T.V. news showing the crash take place. No such tape was ever shown; in fact, it is highly doubtful that such a tape even exists, yet they were as confident in their memory as participants who said they never saw such a tape (Ost et al., 2002).

Memory researchers have studied the relation between confidence and accuracy with children and adults, inside and outside the laboratory, and for many types of events. Overall, confidence and accuracy are weakly related (Busey et al., 2000). People accurately recall many events—even after years pass—and typically are very confident when they do. But people often swear by inaccurate memories too. Even for a distinctive event, a memory can feel "like it just happened yesterday" when, in truth, it's foggy.

Context, State, and Mood Effects on Memory

Our ability to retrieve a memory is influenced not only by the nature of the original stimulus (such as its distinctiveness) but also by aspects of the situation and person. Years ago, two Swedish researchers reported the case of a young woman who was raped while out for a jog (Christianson & Nilsson, 1989). When found by a passerby, she was in shock and could not remember the assault. Over the next 3 months the police took her back to the crime scene several times. Although she could not recall the rape, she became emotionally aroused, suggesting implicit memory of the event. While jogging one day shortly thereafter, she consciously recalled the rape.

Why did her memory return? One possibility is based on the **encoding specificity principle,** *which states that memory is enhanced when conditions present during retrieval match those that were present during encoding* (Tulving & Thomson, 1973). When stimuli associated with an event become encoded as part of the memory, they may later serve as retrieval cues.

Context-Dependent Memory: Returning to the Scene Applying the encoding specificity principle to *external* cues leads us to **context-dependent memory:** *It typically is easier to remember something in the same environment in which it was originally encoded*. Thus, upon returning to your elementary school or old neighborhood, sights and sounds may trigger memories of teachers, classmates, and friends. As with the Swedish jogger, police detectives may take an eyewitness or crime victim back to the crime scene, hoping to stimulate the person's memory.

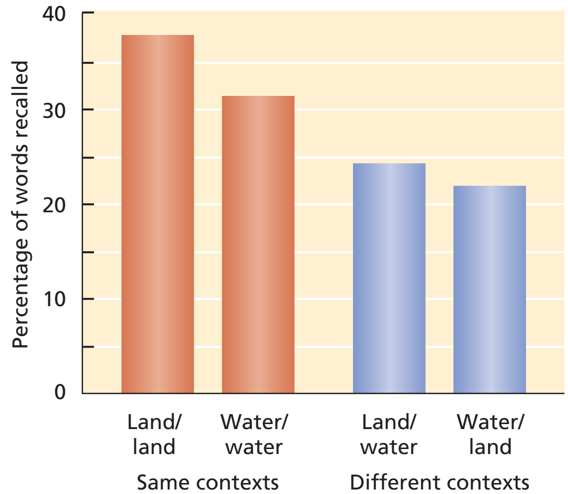
In a classic experiment, Duncan Godden and Alan Baddeley (1975) asked scuba divers to learn some lists of words underwater and some on dry land. As Figure 7.15 shows, when the divers were later retested in the two environments, lists learned underwater were recalled better underwater and those learned on land were better recalled while on land. Many other studies, spanning diverse environmental contexts, have replicated this finding (Smith and Vela, 2001).

Consider how the concept of context-dependent memory might be relevant to your life as a student. In one experiment, when randomly assigned college students studied material in either a quiet or noisy room, they later displayed better memory on short-answer and multiple-choice

11. Are flashbulb memories always accurate? Describe evidence. Are memory accuracy and confidence related?

FIGURE 7.15

Context-dependent memory. Scuba divers who learned lists of words while underwater later recalled them best while underwater, whereas those words they learned on land they best recalled on land. Recall was poorer when the learning and testing environments were mismatched.
SOURCE: Data from Godden & Baddeley, 1975.



questions when tested in a similar (quiet or noisy) environment (Grant et al., 1998). Thus, if you take exams in quiet environments, try to study in a quiet environment.

State-Dependent Memory: Arousal, Drugs, and Mood Moving from external to internal cues, the concept of **state-dependent memory** *proposes that our ability to retrieve information is greater when our internal state at the time of retrieval matches our original state during learning*. The Swedish jogger who was raped consciously remembered her assault for the first time while jogging. In her case, both context-dependent cues (similar environment) and state-dependent cues (arousal while jogging) may have stimulated her memory.

Diverse experiments support this effect. Many students at the campus gym read course materials while exercising on a bicycle, treadmill, or stairclimber machine. Christopher Miles and Elinor Hardman (1998) found that material learned while we are aroused during aerobic exercise is later recalled more effectively if we are once again aerobically aroused, rather than at rest. Conversely, material learned at rest is better recalled at rest.

Many drugs produce physiological effects that directly impair memory, but state-dependent memory also explains why events experienced in a drug state may be difficult to recall later while in a drug-free state (Figure 7.16). Experiments examining alcohol, marijuana, amphetamines, and other drugs have often found that information recall is poorer when there is a mismatch between the person's state during learning and testing (Carter & Cassady, 1998). This *does not* mean, by the way, that drugs improve memory relative to not taking drugs during initial learning.

Does state-dependent memory extend to mood states? Is material learned while in a happy mood or a sad mood better recalled when we are in that mood again? Inconsistent findings suggest that such *mood-dependent memory* is not a reliable phenomenon. Instead, there is more consistent evidence of **mood-congruent recall:** *We tend to recall information or events that are congruent with our current mood* (Fiedler et al., 2001). When happy we are more likely to remember positive events, and when sad we tend to remember negative events. This perpetuates our mood and may be

FIGURE 7.16

State-dependent memory. In the film City Lights, *a drunken millionaire befriends and spends the evening partying with Charlie Chaplin after Chaplin saves his life. The next day, in a sober state, the millionaire doesn't remember Chaplin and considers him an unwanted pest. After getting drunk again, he remembers Chaplin and treats him like a good buddy.*

12. Describe and illustrate encoding specificity, context- and state-dependent memory, and mood-congruent recall.

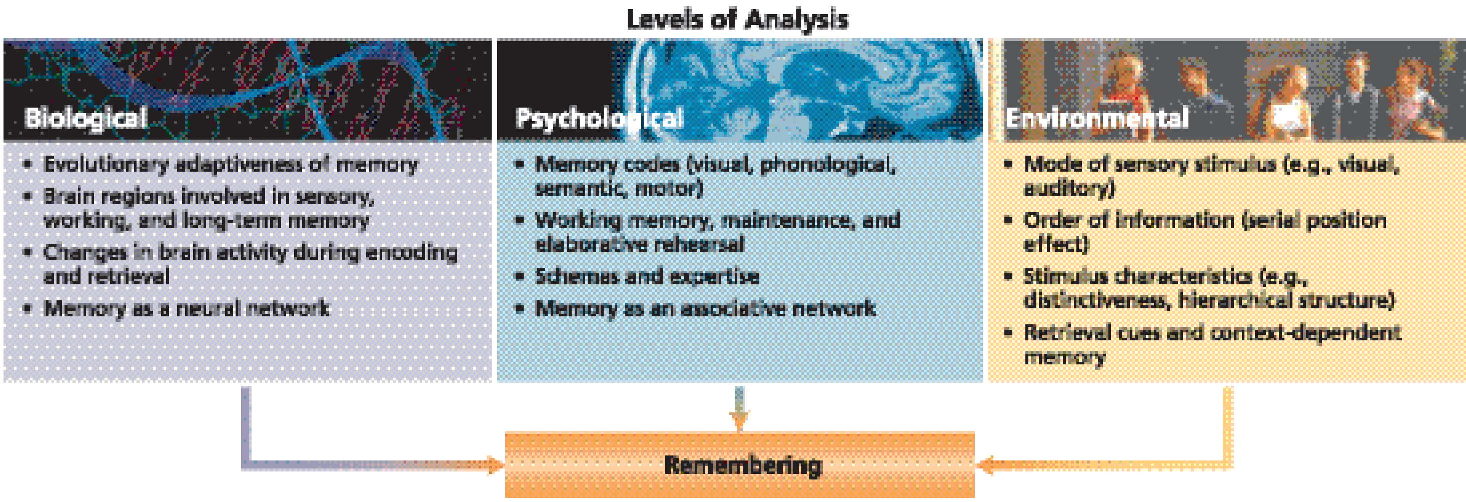


FIGURE 7.17

Understanding behavior: factors that enable us to remember.

one factor that maintains depression once people have entered a depressed state (Pyszczynski et al., 1991).

Thus far we have focused on how information is remembered, and Figure 7.17 summarizes some of the factors involved. We'll have more to say about the brain's role later, but first, in the next two sections we examine why we forget and why we sometimes remember events that never occurred.

IN REVIEW

- *Memory involves three main processes (encoding, storage, and retrieval) and three main components (sensory memory, short-term/working memory, and long-term memory).*
- *Sensory memory briefly holds incoming sensory information. Some information reaches working memory and long-term memory, where it is mentally represented by phonological, visual, semantic, or motor codes.*
- *Short-term/working memory actively processes information and supports other cognitive functions. It has auditory, visuospatial, and executive (coordinating) components. Long-term memory stores enormous amounts of information for up to a lifetime. Studies of amnesia patients and research on the serial position effect support the distinction between short- and long-term memory.*
- *Effortful processing involves intentional encoding and conscious attention. Automatic processing occurs without intention and requires minimal effort.*
- *Deep processing enhances memory. Elaborative rehearsal provides deeper processing than maintenance rehearsal. Hierarchies, chunking, dual-coding by adding visual imagery, and other mnemonic devices facilitate deeper encoding.*
- *Schemas are mental frameworks that shape how we encode information. As we become experts in any given field, we develop schemas that allow us to encode information into memory more efficiently.*
- *People who display exceptional memory take advantage of sound memory principles and mnemonic devices. Researchers disagree as to whether exceptional memory also requires special, innate talent.*
- *Associative network models view long-term memory as a network of associated nodes, with each node representing a concept or unit of information. Neural network models propose that each piece of information in memory is represented not by a single node but by multiple nodes distributed*

throughout the brain. Each memory is represented by a unique pattern of simultaneously activated nodes.

- *Declarative long-term memories involve factual knowledge and include episodic memories (knowledge concerning personal experiences) and semantic memories (facts about the world and language). In contrast, procedural memory is reflected in skills and actions. Explicit memory involves conscious or intentional memory retrieval, whereas implicit memory occurs when memory influences our behavior without conscious awareness.*
- *Retrieval cues activate information stored in long-term memory. Memory retrieval is more likely when we have multiple cues, self-generated cues, and distinctive cues.*
- *We experience flashbulb memories as vivid and clear "snapshots" of an event and are confident of their accuracy. However, over time many flashbulb memories become inaccurate. Overall, memory accuracy and memory confidence are only weakly related.*
- *The encoding specificity principle states that memory is enhanced when cues present during retrieval match those that were present during encoding. Typically it is easier to remember a stimulus when we are in the same environment (context-dependent memory) or same internal state (state-dependent memory) as when the stimulus was originally encoded. One exception is mood states, where we tend to recall information or events that are congruent with our current mood.*

FORGETTING

Some very bright people are legendary for their memory failures. The eminent French writer Voltaire began a passionate letter, "My Dear Hortense," and ended it, "Farewell, my dear Adele." The splendid absentmindedness of English nobleman Canon Sawyer once led him, while welcoming a visitor at the railroad station, to board the departing train and disappear (Bryan, 1986). Indeed, how we forget is as interesting a scientific question as how we remember.

The Course of Forgetting

German psychologist Hermann Ebbinghaus (1885/1964) pioneered the study of forgetting by testing only one person—himself (Figure 7.18). He created over 2,000 *nonsense syllables,* meaningless letter combinations (e.g., *biv, zaj, xew*), to study memory with minimal influence from prior learning, as would happen if he used actual words. In one study, Ebbinghaus spent over 14,000 practice repetitions trying to memorize 420 lists of nonsense syllables.

FIGURE 7.18

Hermann Ebbinghaus was a pioneering memory researcher.

Ebbinghaus typically measured memory by using a method called *relearning* and computing a savings percentage. For example, if it initially took him 20 trials to learn a list but only half as many trials to relearn it a week later, then the savings percentage was 50 percent. In one series of studies, he retested his memory at various time intervals after mastering several lists of nonsense syllables. As Figure 7.19a shows, forgetting occurred rapidly at first and slowed noticeably thereafter.

Perhaps you are dismayed by this finding, which suggests that we quickly forget most of what we learn. Ebbinghaus, however, studied so many lists of nonsense syllables that his ability to distinguish among them undoubtedly suffered. If you learned just one or a few lists of syllables, the general shape of your forgetting curve might resemble Ebbinghaus's over the first 24 hours, but the amount you forgot would likely be much less.

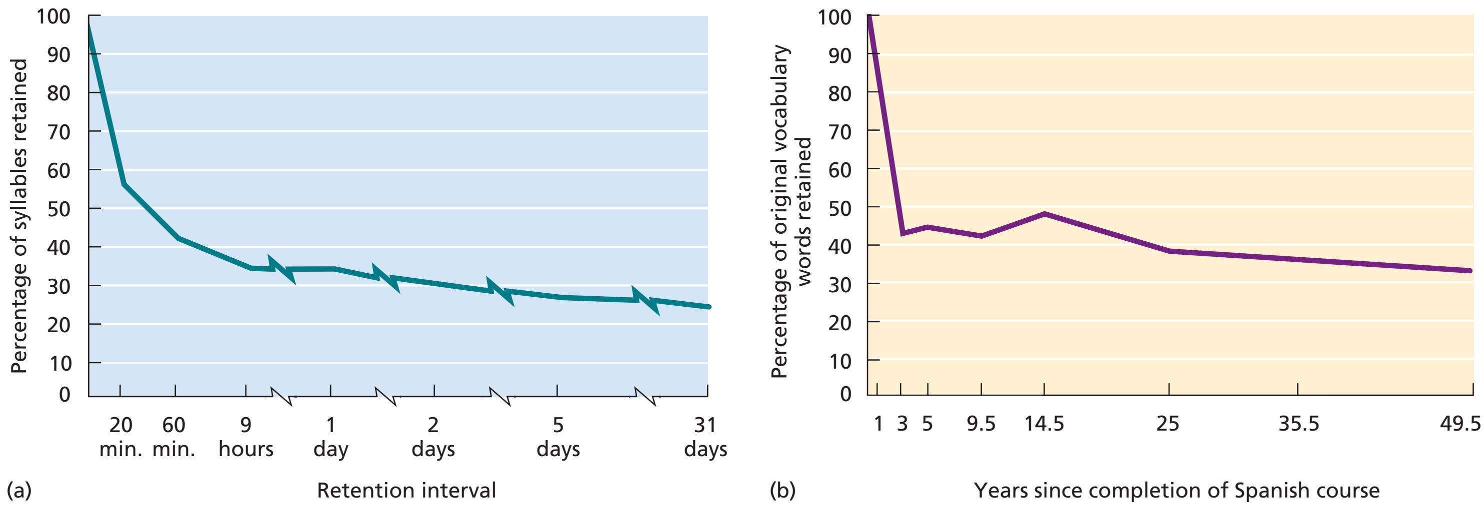


FIGURE 7.19

(a) Hermann Ebbinghaus's forgetting curve shows a rapid loss of memory for nonsense syllables at first, then a more gradual decline. The rapid decline is probably due to the meaningless nature of the nonsense syllables. (b) The forgetting of vocabulary from high school Spanish language classes follows a similar curve, except that the time frame is in years, not days. SOURCES: Data from *(a)* Ebbinghaus, 1964, and *(b)* Bahrick, 1984.

13. Describe Ebbinghaus's research, its value, and its limitations.

Moreover, when material is meaningful (unlike nonsense syllables), we are likely to retain more of it over a longer time.

Consider the forgetting curve shown in Figure 7.19b, based on a study examining the vocabulary retention of people who had studied Spanish in school anywhere from 3 to 50 years earlier and then rarely used it (Bahrick, 1984). Once again, forgetting occurred more rapidly at first, then more slowly as time passed. Notice, however, that the Spanish-retention study employed a time frame of years rather than hours and days as in Ebbinghaus's studies.

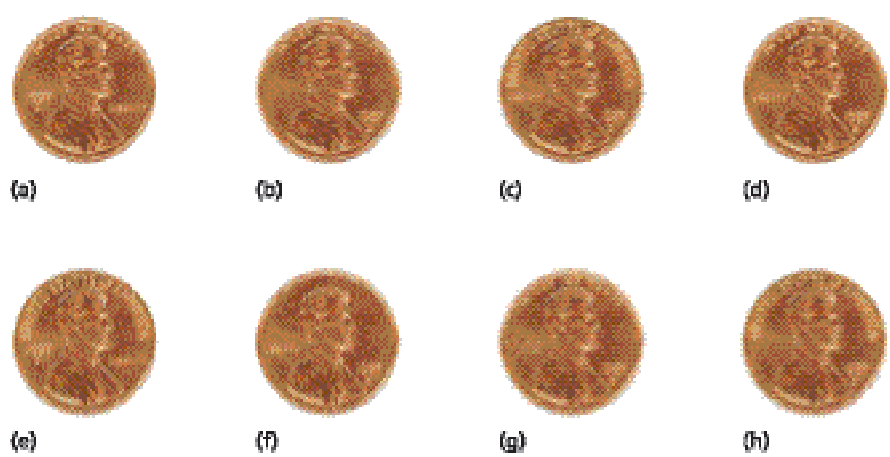


FIGURE 7.20

Which of the coins pictured here corresponds to a real penny? Most people have difficulty choosing the correct one because they have never bothered to encode all of the features of a real penny. If you want to try your skill at picking it out, don't read the next sentence yet. The correct penny is A, the first one. SOURCE: Based on Nickerson & Adams, 1979.

Why Do We Forget?

Given that some memories last a lifetime, why do we forget so much? Researchers have proposed several explanations for normal memory loss, emphasizing difficulties in encoding, storage, and retrieval.

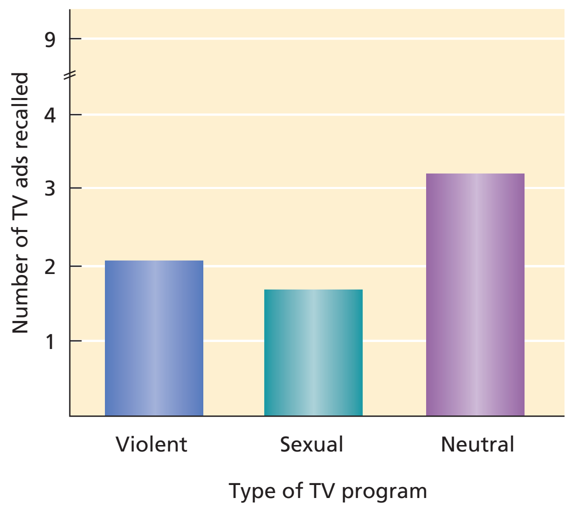
Encoding Failure

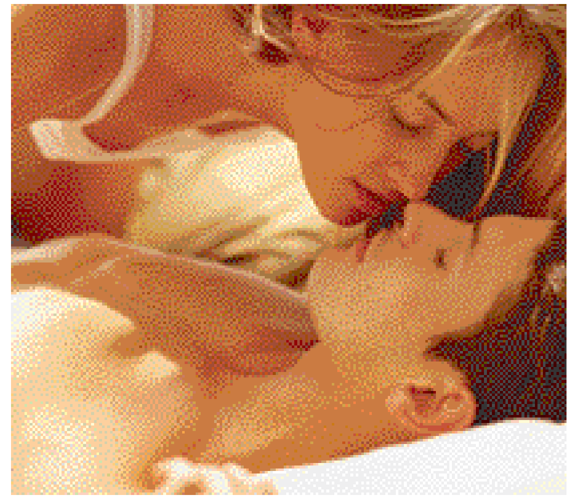
Many memory failures result not from "forgetting" information that we once knew well but from failing to encode the information into long-term memory in the first place Perhaps you had the radio on this morning while showering or eating breakfast, but do you remember every song or news story you heard? Chances are you can recall only the songs or stories that you found particularly interesting. This is because much of what we sense simply is not processed deeply enough to commit to memory.

We noted earlier that few people can draw a penny (or other coin) from memory, with accurate detail. Even when the task is made easier by requiring only recognition, as in Figure 7.20, most people cannot identify the correct coin (Nickerson & Adams, 1979). Can you? The details of a coin's appearance are not meaningful to most of us, and we may not even notice them, no matter how often we see coins in our daily lives.

FIGURE 7.21

In one study, TV viewers who watched programs with violent or sexual content recalled fewer commercials than viewers who watched a neutral program. Source: Data from Bushman and Bonacci, 2002.





At other times, we may notice information but fail to encode it deeply because we turn our attention to something else. Brad Bushman and Angelica Bonacci (2002) randomly assigned 328 adults to watch either a sexually explicit, violent, or neutral TV program. Nine commercial advertisements (e.g., for snacks, cereal, laundry detergent) appeared during each program. Immediately afterward and again a day later, the researchers tested viewers' memory for the ads. When analyzing their findings, Bushman and Bonnaci adjusted for the fact that some of the TV programs were more interesting and arousing than others. Even so, at both time periods, viewers who watched the sexually explicit and violent programs remembered the fewest number of ads (Figure 7.21). Several factors might account for this, and as the researchers proposed, one of them is encoding failure: All the viewers clearly saw the ads, but those watching the sexually explicit and violent programs likely were the most preoccupied with thoughts about the content of the shows.

Decay of the Memory Trace

Information in sensory memory and short-term memory decays quickly with the passage of time. But what happens after a long-term memory is formed? One early explanation for forgetting was **decay theory,** *which proposed that with time and disuse the long-term physical memory trace in the nervous system fades away*. Decay theory soon fell into disfavor because scientists could not identify what physical memory traces were, where they were located, or how physical decay could be measured. In recent decades, however, scientists have begun to unravel some of the ways that neural circuits change when a long-term memory is formed. This research has sparked new interest in examining how these changes might decay over time (Villarreal et al., 2002).

Unfortunately, decay theory's prediction—that the longer the time interval of disuse between learning and recall, the less should be recalled—is problematic. As measured by cued recall and recognition tests, some professional actors display perfect memory for words they had last spoken on stage 2 years earlier—this despite the fact that they had moved on to different acting roles and had learned new scripts (Noice & Noice, 2002b). Moreover, when research participants learn a list of words or a set of visual patterns and are retested at two different times, they sometimes recall material during the second testing that they could not remember during the first. This phenomenon, called *reminiscence,* seems inconsistent with the concept that a memory trace decays over time (Greene, 1992). In sum, scientists still debate the validity of decay theory.

Interference

According to *interference theory,* we forget information because other items in long-term memory impair our ability to retrieve it (Postman & Underwood, 1973). Figure 7.22 illustrates two major types of interference. **Proactive interference** *occurs when material learned in the past interferes with recall of newer material*. Suppose that Alison changes residences, acquires a new phone number, and memorizes it. That night she sees a friend who asks for her new number. When Alison tries to recall it, she can remember only two or three digits, and instead keeps remembering the digits of her old phone number. Memory of her old

14. Explain why we forget based on concepts of encoding failure, decay, and interference. What causes TOT experiences?

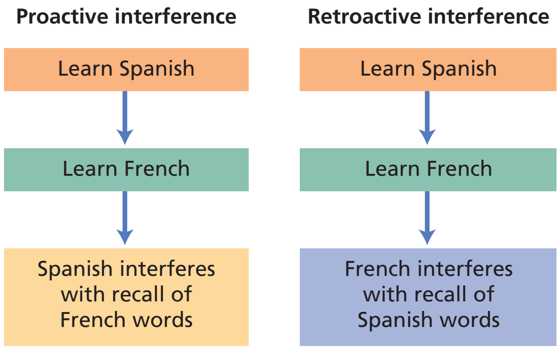


FIGURE 7.22

Interference is a major cause of forgetting. With proactive interference, older memories interfere with the retrieval of newer ones. With retroactive interference, newer memories interfere with the retrieval of older ones.

phone number is interfering with her ability to retrieve the new one.

Retroactive interference *occurs when newly acquired information interferes with the ability to recall information learned at an earlier time* (Tulving & Psotka, 1971). Suppose Alison has now had her new phone number for several months and recalls it perfectly each time. If we ask her, "What was your old phone number?" Alison may have trouble remembering it, perhaps mixing up the digits with her new number. In general, the more similar two sets of information are, the more likely it is that interference will occur. Alison (or you) would probably experience little interference in recalling highly dissimilar material, such as her new phone number and French vocabulary.

Some researchers believe that interference is caused by competition among retrieval cues (Anderson & Neely, 1996). When different memories become associated with similar or identical retrieval cues, confusion can result and accessing a cue may "call up" the wrong memory. Retrieval failure also can occur because we have too few retrieval cues or the cues may be too weak.

Almost all of us have experienced a retrieval problem called the **tip-of-the-tongue (TOT) state**, *in which we cannot recall something but feel that we are on the verge of remembering it*. The title of the radio quiz show "Wait, Wait—Don't Tell Me!" plays on this phenomenon. When Bennett Schwartz (2002) asked 56 college students to record a diary for 4 weeks, he found that they averaged just over one TOT experience per week. Most often, TOT states were triggered by the inability to remember the name of an acquaintance, famous person, or object. Students usually felt emotional while wrapped up in a TOT state and were relieved when the answer arrived. Sooner or later, it usually did. The answer often "popped into mind" spontaneously, but in many cases students had to consult a book or another person.

What Do You Think?

IS IT REALLY ON THE TIP OF YOUR TONGUE?

Suppose you're having a TOT experience. Should we always assume that it's a retrieval problem? What else might explain your inability to come up with the answer? Think about it, then see page 140.

Motivated Forgetting

Psychodynamic and other psychologists propose that at times, people are consciously or unconsciously motivated to forget. During therapy sessions, Sigmund Freud often observed that his patients remembered traumatic or anxiety-arousing events that had long seemed "forgotten." For example, one of his patients suddenly remembered with great shame that while standing beside her sister's coffin she had thought, "Now my brother-in-law is free to marry me." Freud concluded that the thought had been so shocking and anxiety arousing that the woman had *repressed* it—pushed it down into her unconscious mind—there to remain until it was uncovered years later during psychoanalysis. **Repression** *is a motivational process that protects us by blocking the conscious recall of anxiety-arousing memories.*

The concept of repression is highly controversial. Some evidence supports it, and other evidence does not (Karon, 2002). People certainly do forget unpleasant events—even traumatic ones—yet they also forget very pleasant events. If a person cannot remember a negative experience, is this due to repression or to normal information-processing failures (Epstein & Bottoms, 2002)? Overall, it has been difficult to demonstrate experimentally that a special process akin to repression is the cause of memory loss for anxiety-arousing events (Holmes, 1990). We will return to this topic shortly.

Amnesia

The most dramatic instances of forgetting occur in amnesia, which takes several forms. **Retrograde**

amnesia *represents memory loss for events that took place sometime in life before the onset of amnesia*. For example, H. M. suffered mild memory loss for events in his life that had occurred during the year or two *before* he had his operation. Football players experience retrograde amnesia when they are "knocked out" in a concussion, regain consciousness, and cannot remember the events just before being hit.

Anterograde amnesia *refers to memory loss for events that occur after the initial onset of amnesia*. H. M.'s brain operation, and particularly the removal of much of his hippocampus, produced severe anterograde amnesia and robbed him of the ability to consciously remember new experiences and facts. In a similar fashion, the woman whose hand was pinpricked by Claparède during a handshake also experienced anterograde amnesia; moments later she could not consciously remember the episode. Unlike H. M.'s anterograde amnesia, hers was caused by *Korsakoff's syndrome,* which can result from chronic alcoholism and may also cause severe retrograde amnesia.

Alzheimer's disease, the most common form of senile dementia that affects millions of elderly adults, produces severe retrograde and anterograde amnesia. This memory loss may be due to a decline in the function of several neurotransmitter systems, especially the acetylcholine system (Ballard, 2002). Acetylcholine plays a key role in synaptic transmission in several brain areas involved in memory.

Finally, there is one type of amnesia that almost all of us encounter: an inability to remember personal experiences from the first few years of our lives. Even though infants and preschoolers can form long-term memories of events in their lives (Peterson & Whalen, 2001), as adults we typically are unable to recall these events consciously. This *memory loss for early experiences is called* **infantile amnesia** (also known as *childhood amnesia*). Our memories of childhood typically do not include events that occurred before the age of 3 or 4, although some adults can partially recall major events (e.g., the birth of sibling, hospitalization, or a death in the family) that happened before the age of 2 (Eacott & Crawley, 1998).

15. Why is motivated forgetting a controversial concept? Describe types of amnesia and the nature of prospective memory.

What causes infantile amnesia? One hypothesis is that brain regions that encode long-term episodic memories are still immature in the first years after birth. Another is that we do not encode our earliest experiences deeply and fail to form rich retrieval cues for them. Additionally, because infants lack a clear self-concept, they do not have a personal frame of reference around which to organize rich memories (Harley & Reese, 1999).

Forgetting to Do Things: Prospective Memory

Have you ever forgotten to mail a letter, turn off the oven, keep an appointment, or purchase something at the market? In contrast to *retrospective memory,* which refers to memory for past events, **prospective memory** *concerns remembering to perform an activity in the future*. That people forget to do things as often as they do is interesting, because prospective memories typically involve little content. Often we need only recall that we must perform some event-based task ("Remember, on your way out, mail the letter") or time-based task ("Remember, take your medication at 4 P.M."). Successful prospective memory, however, draws on other cognitive abilities, such as planning and allocating attention while performing other tasks (Kliegel et al., 2002).

Are people with better retrospective memory less likely to be forgetful on prospective memory tasks? In one experiment, researchers assessed participants' retrospective memory ability by having them recall lists of words (Wilkins & Baddeley, 1978). Next, participants performed a prospective simulated pill-taking task by carrying around a small box with a button. Four times a day at a specified time they had to remember to press the button, which time-stamped their response. Overall, participants who performed better on the word-recall task did not display better memory on the simulated pill-taking task.

During adulthood, do we become increasingly absentminded about remembering to do things, as a common stereotype suggests? Numerous laboratory experiments support this view (Vogels et al., 2002). Typically, participants perform a task that requires their ongoing attention while trying to remember to signal the experimenter at certain time intervals or whenever specific events take place. Older adults generally display poorer prospective memory, especially when signaling is time-based. However, when prospective memory is tested outside the laboratory using tasks such as simulated pill-taking, healthy adults in their 60s to 80s often perform as well as or better than adults in their 20s (Rendell & Thomson, 1999). Perhaps older adults are more motivated to remember in such situations, or they rely more on habit and setting up a standard routine (Anderson & Craik, 2000). In sum, prospective memory—like other areas of memory—is far from simple.

IN REVIEW

- *Forgetting tends to be most rapid relatively soon after initial learning, but the time frame and degree of forgetting can vary widely depending on many factors.*
- *Due to encoding failure, we often cannot recall information because we never entered it into long-term memory in the first place.*
- *Decay theory proposes that physical memory traces in long-term memory deteriorate with disuse over time, but evidence of reminiscence contradicts this view.*
- *Proactive interference occurs when material learned in the past interferes with recall of newer material. Retroactive interference occurs when newly acquired information interferes with the ability to recall information learned at an earlier time.*
- *Psychodynamic theorists propose that we may forget anxiety-arousing material through repression, an unconscious process of motivated forgetting.*
- *Retrograde amnesia represents memory loss for events that occurred* prior *to the onset of amnesia. Anterograde amnesia refers to memory loss for events that occur* after *the initial onset of amnesia. Infantile amnesia is our inability to remember personal experiences from the first few years of our lives.*
- *Whereas retrospective memory refers to memory for past events, prospective memory refers to our ability to remember to perform some activity in the future.*

MEMORY AS A CONSTRUCTIVE PROCESS

Retrieving information from long-term memory is not like viewing a video taped replay. Our memories of things past often are incomplete or sketchy. In such situations, we may literally *construct* (or as some say, *reconstruct*) a memory by piecing together bits of stored information in a way that intuitively "makes sense" and seems real and accurate. As our earlier discussion of flashbulb memories illustrated, at times we may be highly confident of memories that in fact are partly, or completely, inaccurate.

Memory construction can be amusing at times, and a tendency to recall the world through slightly rosy glasses can even help us feel good about ourselves. For example, when college students in one study recalled their high school grades, the worse the grade was, the less often students remembered it accurately. Students correctly recalled almost all of their As, but only a third of Ds (Figure 7.23). Most important, errors were positively biased; students usually misremembered their Bs as having been As, their Cs as Bs, and their Ds as Cs. (Bahrick et al., 1996). As we will see, however, memory construction also can have serious personal and societal consequences.

Memory Distortion and Schemas

Decades ago, Sir Frederick Bartlett (1932) asked residents of Cambridge, England, to read stories and then retell them days or months later. One story, a Pacific Northwest Indian tale called "The War of the Ghosts," describes two young men who go down to a river to hunt seals. While there, warriors in canoes come up the river, and one of the young men agrees to join them for a raid on a

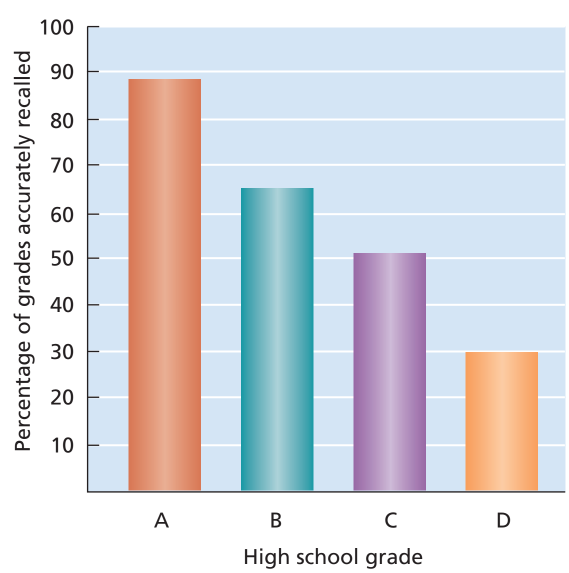
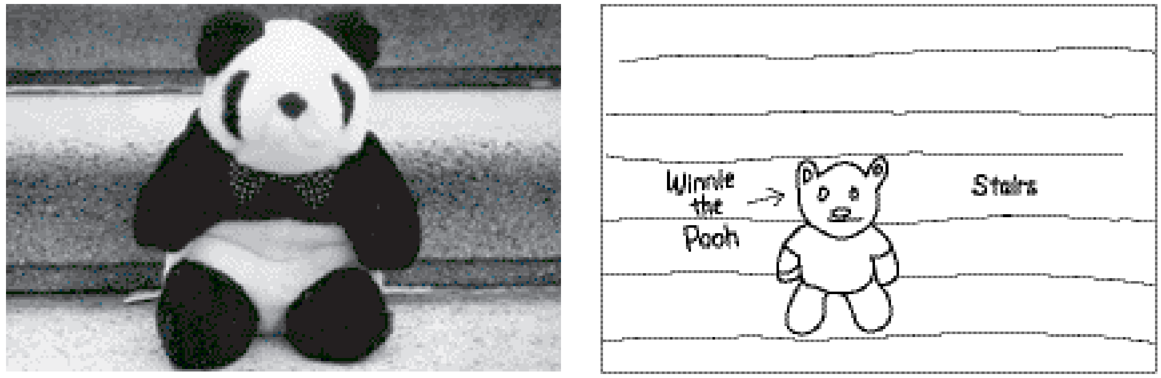


FIGURE 7.23

The lower the grade, the smaller the percentage of students who accurately recalled it. Note also that when students incorrectly recalled a grade, they almost always overestimated how well they did.



(a) (b)

FIGURE 7.24

Boundary extension. (a) What you see. (b) What you remember. Helene Intraub and her colleagues (1996) have found that when people briefly look at close-up pictures, such as this one of a teddy bear, and then draw the pictures from memory, they unknowingly convert the image into a "wider-angle scene" in which the size of the main object (e.g., the teddy bear) shrinks. This effect is less likely to occur if the original picture already is a wide-angle scene. Images courtesy of Helene Intraub.

town. During the raid, the man discovers that his companions are ghosts, and later he dies a mysterious death.

Bartlett's participants, however, were 20th-century residents of England, not 18th-century Native Americans. When they retold the story, they partly reconstructed it in a way that made sense to them. For example, 20 hours after reading "The War of the Ghosts," one participant shortened the story by almost half, described the hero as fishing rather than as hunting seals, substituted the word *boat* for *canoe,* and said that the enemy—not his companions—were ghosts. Bartlett found that the longer the time interval between the reading and retelling of the story, the more the story changed to fit English culture.

Bartlett, who coined the term *schema,* believed that people have generalized ideas (schemas) about how events happen and that they use these ideas to organize and construct their memories. As we described earlier, schemas often enhance memory by helping us organize and understand information (recall the clothes-washing description). The price, however, is that schemas may distort our memories by leading us to encode or retrieve information in ways that "make sense" and fit in with our preexisting assumptions about the world.

16. Discuss examples of memory construction and explain how schemas influence this process.

Quite literally, memory construction extends to how we visualize the world (Intraub, 2002). As Figure 7.24 illustrates, when college students in one study looked at photographs that had a main object within a scene and then drew what they saw from memory, they consistently displayed *boundary extension:* remembering the scene as more expansive—as being "wider-angle"—than it really was (Intraub et al., 1996). In real life, objects usually occur against an expansive background, creating a schema for how we expect scenes to look. Thus when remembering close-up images, our schemas lead us to "see beyond the edge" and retrieve a broader scene, not the one we saw.

Advertisers often exploit people's tendency to elaborate and change their memories, thereby skirting laws against false advertising. Consider the following commercial for the mouthwash Listerine.

> "Wouldn't it be great," asks the mother, "if you could make him coldproof? Well, you can't. Nothing can do that. [Boy sneezes.] But there is something you can do that may help. Have him gargle with Listerine antiseptic. Listerine can't promise to keep him cold-free, but it may help him fight off colds. During the cold-catching season, have him gargle twice a day with full-strength Listerine. Watch his diet, see he gets plenty of sleep, and there's a good chance he'll have fewer colds, milder colds, this year." (Anderson, 1980, p. 203)

This commercial, with the product's name changed to *Gargoil,* was used in a memory experiment (Harris, 1977). When participants were asked to recall the commercial, they agreed with the statement "Gargoil antiseptic helps prevent colds," although the commercial *did not* say that. (It said "Gargoil *may* help.") Participants elaborated on what the ad said when they constructed their memories. Undoubtedly, this is what the advertisers hoped for. The following "Research Close-Up" offers some insight into how schemas can affect memory and lead us to remember things that never happened.

Misinformation Effects and Eyewitness Testimony

If memories are constructed, then information that occurs *after* an event may shape that construction process. This **misinformation effect,** *the*

RESEARCH CLOSE-UP

MEMORY ILLUSIONS: REMEMBERING THINGS THAT NEVER OCCURRED

Study 1: College Students

Background

In this famous experiment, Henry Roediger III and Kathleen McDermott examined how often false memories occurred while people performed a simple laboratory task: remembering lists of words. They also investigated whether false memory rates depend on how memory is measured (i.e., recall versus recognition) and whether people experience false memories as being vivid and clear.

Method

Building on previous research (Deese, 1959), the researchers created 24 lists of 15 words. Each list contained words that, to varying degrees, were associated with a central organizing word. To illustrate, look at the following list:

> *sour, candy, sugar, bitter, good, taste, tooth,*
> *nice, honey, soda, chocolate, heart, cake, tart, pie*

The word *sweet* doesn't occur in the list, yet it is associated with these items. The central word *(sweet)* is called a *critical lure.*

Thirty-six college students each listened to 16 of the 24 lists. For 8 lists, students' recall was measured as soon as each list ended. For 8 other lists, recall was not measured. After finishing all 16 lists, students performed a recognition task. They were given a sheet of paper with 96 words, half of which actually had been on the lists. The other words were critical lures and filler items from the final 8 lists not read to each student. Students identified whether each word had been on the lists they heard. If they selected a word, they also reported whether they had a vivid memory of having heard it or, instead, were sure that they had heard it but lacked a vivid memory.

Results

Students correctly recalled 62 percent of the real words but falsely recalled almost as many (55 percent) of the critical lures. For the 8 lists where students performed only a recognition task, they correctly identified words 62 percent of the time but falsely identified even more of the critical lures (72 percent). Furthermore, in just over half of the cases where students falsely recognized a critical lure, they reported having a vivid memory of it.

Discussion

Although critical lures were never presented, students falsely recalled them half the time and falsely recognized them almost three quarters of the time. Moreover, students often reported having a clear memory of the nonexistent critical lure. Many researchers have replicated this finding.

What causes these false memories? Roediger and McDermott (1995, 2000) argue that hearing the words activates an associative network—a schema—for the critical lure. For some people, the words (*sour, candy, sugar,* etc.) may consciously trigger a thought of "sweet." For others, spreading activation from the words unconsciously primes the concept of "sweet." (Look back at Figure 7.12. If you heard the words *roses, fire, cherries, orange, apple,* they would prime the word *red*). Whether consciously or unconsciously, the critical lure is activated. This creates a problem during retrieval, because people may misinterpret the source of activation and thus falsely remember the lure as being on the list (Figure 7.25a).

In your view, are these findings relevant to everyday memory in the real world? Critics emphasize that the research context—college students learning word lists—may have little relevance to situations involving memory for important events. Yet Roediger and McDermott argue that this research context makes the findings more impressive. Participants knew it was a memory test and knew that inaccurate memories would be spotted. Further, memory was tested soon after hearing each list, and "we used college students—professional memorizers—as subjects." If people can be highly confident of their false memories in this straightforward situation, the researchers ask, then what might happen in real-world contexts where conditions for remembering events are more complex and not as optimal?

Study 2: People Reporting Abduction by Aliens

Background

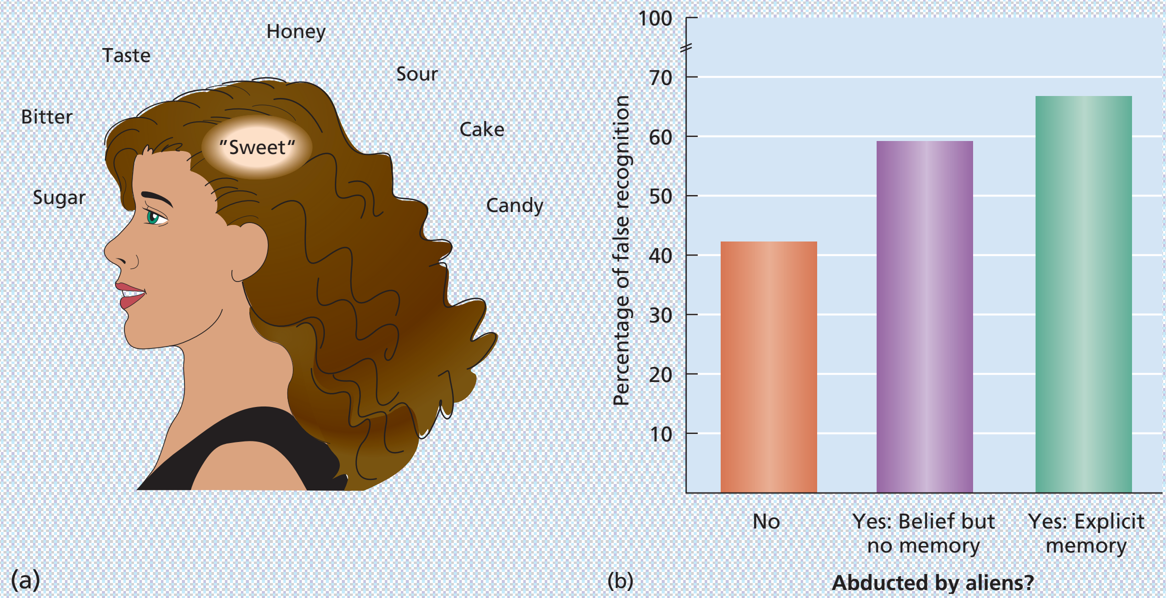
Is there a relation between false memories on the word-list task in Study 1 and false memories for significant events in real life? To examine this question, Susan Clancy and coworkers recruited three groups of participants through newspaper advertisements: a control group of 13 people who said they

Continued

SOURCES: Henry L. Roediger III and Kathleen McDermott (1995). Creating false memories: Remembering words not presented in lists. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 21,* 803–814.
Susan A. Clancy, Richard J. McNally, Daniel L. Schacter, Mark F. Lenzeweger, and Roger K. Pitman. (2002). Memory distortion in people reporting abduction by aliens. *Journal of Abnormal Psychology, 111,* 455–461.

FIGURE 7.25

(a) After listening to a list of related words, people often remember hearing a critical lure ("sweet") that was never presented. (b) The degree of false recognition of critical lures among three groups of participants. SOURCE: Data from Clancy et al., 2002.



had never been abducted by aliens, 9 people who were sure they had been abducted by aliens but who had no explicit memory of it, and 11 people who said that, for a time, they had forgotten that they had been abducted but then had a clear memory of the abduction gradually return to them. Why study people claiming to be alien abductees? Because, say the researchers, these individuals are reporting a major traumatic event that in reality we can assume is unlikely to have occurred.

Procedure and Results

Participants listened to word lists of varying lengths, based on the lists used in Study 1. The three groups did not differ in how accurately they recalled and recognized words that actually had been on the lists. However, the two abductee groups falsely recalled and falsely recognized more critical lures than the control group, and those with explicit memories of abduction made the most recognition errors (Figure 7.25b).

Discussion

The authors note that, assuming the alien abductions were unlikely to have occurred, the findings indicate a relation between how prone people are to display false memories both inside and outside the laboratory. They also speculate that both types of false memories may share a common basis: a confusion over the source of the memory. In the lab, spreading activation caused by the word lists is mistakenly attributed to a false source: the presence of a critical lure that actually was not on the list. A similar type of confusion could occur, for example, when "an individual might watch a movie about alien abductions as a child and then—years later—come to believe that the events in the movie actually occurred because he or she has forgotten the actual source of the memory."

17. How did the *Research Close-Up* studies investigate false memories? What might have caused the false memories?

distortion of a memory by misleading postevent information, has frequently been investigated in relation to mistaken eyewitness testimony. In one celebrated case, Father Bernard Pagano, a Roman Catholic priest, was positively identified by seven eyewitnesses as the perpetrator of a series of armed robberies in the Wilmington, Delaware, area. He was saved from almost certain conviction when the true robber, dubbed the "gentleman bandit" because of his politeness and concern for the victims, confessed to the crimes. You can see in Figure 7.26 that there was little physical resemblance between the two men.

Two pieces of information may have affected the witnesses' memory. First, the gentlemanly and concerned manner of the robber is consistent with the schema many people have of priests. Second, before presenting pictures of suspects to the eyewitnesses, the police let it be known that the suspect might be a priest. Father Pagano was the only suspect wearing a clerical collar, and the witnesses' memories may have been strongly affected by this information (Tversky & Tuchin, 1989).

Even one or two words can produce a powerful misinformation effect while questioning an eyewitness. Imagine that after you witness a two-car crash, a police officer takes your statement and simply asks you, "About how fast were the cars going when they *contacted* each other?" In one experiment, college students viewed brief films of car accidents and then judged how fast the cars were going. As Figure 7.27 shows, the judged speed increased by about 33 percent when the word *contacted* was changed to *hit, bumped, collided with, or smashed into.* (Loftus & Palmer, 1974).

Misinformation effects also occur because of **source confusion,** *our tendency to recall something or recognize it as familiar but to forget where we encountered it.* Suppose an eyewitness to a crime looks through a series of mug shots and reports that none of the individuals is the perpetrator. Several days later, the eyewitness is brought back to view a live lineup and is asked to identify the person who committed the crime. In reality, none of the people in the lineup did, but one suspect was pictured in a mug shot that the eyewitness had seen days earlier. "That's the person," says the eyewitness. Source confusion (also called *source monitoring error*) occurred because the eyewitness recognized that the individual's face was familiar but failed to remember that this familiarity stemmed from the mug shot. Instead, the witness mistakenly assumed that he or she saw the familiar-looking suspect committing the crime.

In an experimental analog to this situation, 29 percent of participants who witnessed a staged event and later viewed mug shots misidentified *innocent* suspects as having been involved in the event because of source confusion (Brown et al., 1977). Source confusion also occurs when people witness an event (e.g., a video of a home burglary) and then are exposed to misleading statements about it (e.g., that a bare-handed, unarmed burglar wore gloves and had a gun). They may eventually forget that the source of the misinformation was a question or statement made by someone else and come to believe it was part of what they saw while witnessing the event (Mitchell & Zaragoza, 2001).

Does postevent information permanently alter a witness's original memory so that the original memory can never again be retrieved? Researchers debate the answer, but all agree that eyewitness reports can be influenced by postevent information. Results like these have raised concerns about the reliability of eyewitness testimony not only from adults but also from children in cases of alleged physical and sexual abuse.

18. Describe the misinformation effect, why it occurs, and how it affects memory accuracy in children and adults.

For more on the dilemma of eyewitness testimony, see Video Clip 7.2.

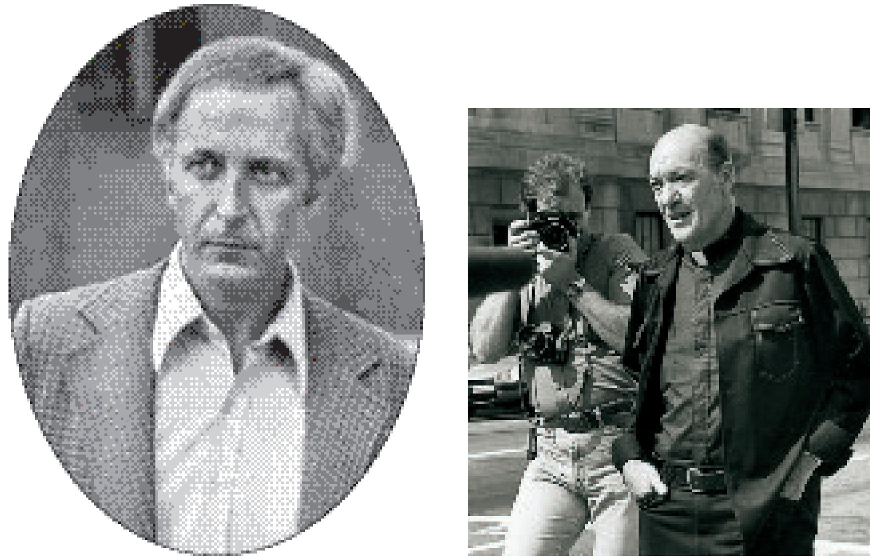
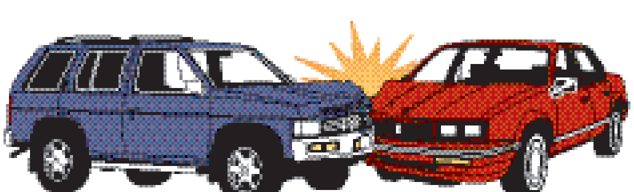


FIGURE 7.26

Seven eyewitnesses to armed robberies committed by Ronald Clouser (a) mistakenly identified Father Bernard Pagano (b) as the robber, probably as a result of information from police that influenced their memory reconstructions. United Press International.



How fast were the two cars going when they ____________ each other?

Words	Perceived speed
smashed into	41 mph
collided with	39 mph
bumped into	38 mph
hit	34 mph
contacted	31 mph

FIGURE 7.27

College students' memory of how fast two cars were moving just before an accident varied significantly depending on how the question was phrased.

The Child as Eyewitness

In cases of alleged child sexual abuse, there is often no conclusive corroborating medical evidence and the child is usually the only witness (Bruck et al., 1998). If the charges are true, the thought of failing to convict the abuser and returning the child to an abusive environment is frightening. Conversely, if the charges are false, the consequences of convicting an innocent person are equally distressing.

Accuracy and Suggestibility

As with adults, a single instance of suggestive questioning can distort some children's memory, but suggestive questioning most often leads to false memories when it is repeated. Young children are typically more susceptible to misleading suggestions than older children (Ceci et al., 2000).

In one experiment by Michelle Leichtman and Stephen Ceci (1995), 3- to 6-year-old children were told about a man named Sam Stone. Over several weeks, some children were repeatedly told stories that portrayed Sam as clumsy. Later "Sam" visited their classroom, was introduced, and behaved innocuously. The next day, the children were shown a ripped book and soiled teddy bear, things for which Sam was not responsible. Over the next 10 weeks they were interviewed several times, and some were asked suggestive questions about Sam (e.g., "When Sam Stone tore the book, did he do it on purpose or was he being silly?"). Two weeks later a new interviewer asked all the children to describe Sam's visit to the classroom.

Children who heard suggestive information about Sam—whether before, after, or especially before *and* after Sam's appearance—made more false reports about Sam's behavior than a control group that never heard suggestive information. One child stated that after soaking the teddy bear in the bath, Sam smeared it with a crayon. These findings are troubling, because during many sexual abuse investigations, the child initially denies being abused, and then after repeated suggestive questioning during therapy or police interviewing, the child acknowledges the abuse (Bruck et al., 1998). Was the child understandably reluctant to open up at first, or did suggestive questions produce a false allegation?

How well do children remember traumatic events? Elaine Burgwyn-Bailes and coworkers (2001) interviewed 3- to 7-year-olds a few days, 6 weeks, and 1 year after the children underwent emergency plastic surgery for facial lacerations. At each time period, children accurately remembered most of the details of their operation, but they also mistakenly agreed with about 15 percent of leading questions ("Did the doctor's helper use any needles?") and suggestive questions ("The lady took off your watch, didn't she?") about events that never occurred. Compared to older children, younger children remembered fewer true details and agreed more often to leading and suggestive questions.

True Versus False Reports: Can Professionals Tell Them Apart?

Can professionals reliably distinguish between children's accurate and false reports? The answer appears to be no, at least when false reports are caused by repeated, suggestive questioning. Mental-health and social workers, prosecutors, and judges shown videotapes of children's reports in the Sam Stone experiment often rated false reports as highly credible, perhaps because many children who make them are not intentionally lying. Rather, the children believe that their memory is accurate. After suggestive questioning, children are as confident of their false memories as they are of their accurate ones (Roebers, 2002).

What should society do? Like adults, young children accurately remember a lot, but they also misremember and are susceptible to repeated suggestive questioning. Thanks to psychological research, law enforcement, mental-health, and legal professionals are now paying more attention to how children's admissions of abuse are elicited, and training programs are helping practitioners minimize suggestive interviewing techniques (Sternberg et al., 2002). The goal is not to discredit children's allegations of abuse. To the contrary, the hope is that by minimizing the risk of false allegations, nonsuggestive interviewing will elicit allegations judged as even more compelling, thereby helping to ensure that justice is done.

The "Recovered Memory" Controversy

In 1997, a woman from Illinois settled a lawsuit against two psychiatrists and their hospital for $10.6 million. She alleged that her psychiatrists used hypnosis, drugs, and other treatments that led her to develop false memories of having been a high priestess in a sexually abusive satanic cult

FIGURE 7.28

In a famous 1990 repressed-memory case, George Franklin was convicted of murdering Susan Nason, an 8-year-old girl killed in 1969. Franklin's 28-year-old daughter Eileen (shown here), who had been Susan's childhood friend, provided the key evidence. During therapy Eileen recovered memories of her father sexually assaulting and killing Susan. A judge overturned the conviction after learning that Eileen's memories had been recovered under hypnosis. All of the details about the case that Eileen recalled had been published in the newspapers, creating the possibility of source confusion in her memory. Eileen also had other recovered memories that were proven to be untrue, such as those of her father killing two other girls. Shahn Kermuni, Gamma Liaison.

(APA Monitor, December 1997, p. 9). Yet only years earlier, there had been a wave of cases in which adults—usually in the course of psychotherapy—began to remember long-forgotten childhood sexual abuse and sued their parents, other family members, and former teachers for the alleged trauma (Figure 7.28).

The scientific controversy over the validity of "recovered memories" of childhood trauma can be broken down into two issues. First, when a recovered memory of sexual abuse occurs, is it accurate? Second, if the abuse really happened, what caused the memory to be forgotten for so long—repression, or some other psychological process?

Let's briefly examine the second issue. Many scientists and therapists question Freud's concept of repression. Repression implies a special psychological mechanism that actively pushes traumatic memories into the unconscious mind, and we have already noted that researchers have had difficulty demonstrating it experimentally. Recovered memories of childhood sexual abuse or other traumas cannot be taken as automatic evidence of repression. Memory loss may have occurred because of ordinary sources of forgetting or because the victim intentionally avoided thinking about the abuse or reinterpreted the trauma to make it less upsetting (Epstein & Bottoms, 2002). But beyond these factors, other researchers and many therapists believe that repression is a valid concept (Karon, 2002). This controversy will not be resolved soon.

What about the more basic question? Can someone forget childhood sexual abuse, by whatever psychological mechanism, and then recover that memory as an adult? Indeed, full or partial memory loss for a traumatic event has been reported among survivors of natural disasters, children who witnessed the violent death of a parent, victims of rape, combat veterans, and victims of sexual and physical abuse (Arrigo & Pezdek, 1997; Epstein & Bottoms, 2002). Moreover, laboratory experiments indicate that a mentally shocking event (e.g., viewing a sudden, violent film scene) can produce retrograde amnesia for information presented just before the shocking event occurred (Loftus & Burns, 1982).

Some victims of documented child sexual abuse do not recall their trauma when they are adults, and accurate memories of the abuse can indeed return after many years of posttrauma forgetting (Kluft, 1999; Williams, 1995). Yet memory loss after psychological trauma is usually far shorter, with memory returning over weeks, months, or perhaps a few years. In many cases of trauma, the victim's primary problem is not memory loss but rather an *inability* to forget, which may involve involuntary nightmares or flashbacks (Berntsen, 2001).

Experiments indicate that college students may develop false memories of personal childhood events that never happened—being hospitalized overnight for a high fever, accidentally spilling a bowl of punch on the parents of the bride at a wedding reception, being rescued by an elderly lady while lost and crying in a shopping mall—after being exposed to suggestive questioning or merely by repeatedly imagining that the event took place (Hyman et al., 1995). Obviously, these events do not approximate the magnitude of experiencing sexual abuse, and for ethical reasons experimenters do not test whether false memories of sexual abuse can be implanted. Nevertheless, say many researchers and clinicians, add these findings to everything science has taught us about forgetting, constructive memory,

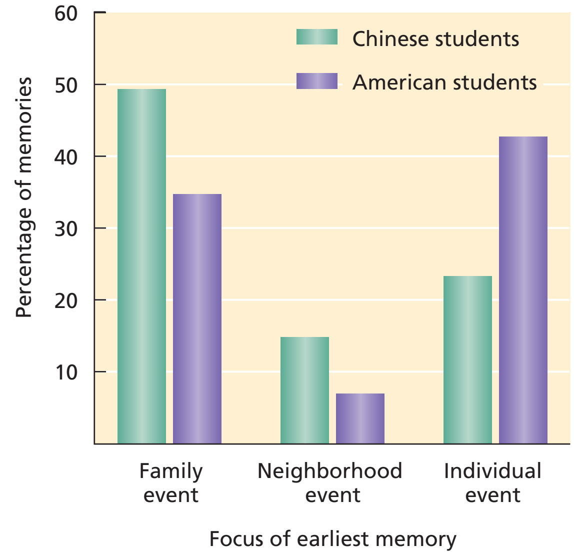


FIGURE 7.29

What is your earliest memory? In this study, Chinese students recalled events that, overall, were more family and neighborhood oriented than events recalled by American students. How else might our cultural upbringing and worldview influence memory? SOURCE: *Data from Wang, 2002.*

and the "fogging up" of even flashbulb memories, and the conclusion is that we should not take the accuracy of recovered memories at face value (Pickrell et al., 2003). They are especially concerned that in "recovered-memory therapy," therapists repeatedly suggest the possibility of abuse to people who are already emotionally vulnerable.

The message from science is not that all claims of recovered traumatic memories should be dismissed. Rather, it is to urge caution in unconditionally accepting those memories, particularly in cases where suggestive techniques are used to recover the memories (Brandon et al., 1998). Some day it may be possible scientifically to separate true memories from false ones. Researchers have begun to examine whether some types of true versus false memories are associated with different patterns of brain activity, and true memories often are described in greater detail than false ones. But at present, these findings cannot be used to determine reliably whether any individual memory is true or false (Pickrell et al., 2003).

19. Discuss the recovered memory controversy, the two key issues involved, and relevant evidence.

Culture and Memory Construction

Culture and memory have a reciprocal relation. On the one hand, whether through modeling, print or electronic media, or oral traditions, cultural survival depends on transmitting knowledge and customs from one generation to the next. Without our capacity to remember events and information, culture simply could not exist (and neither could we, as a species).

At the same time, culture influences memory. Our cultural upbringing shapes the schemas—the mental frameworks—that we acquire and use to perceive ourselves and the world. For example, as we discussed in Chapter 1, most people living in northern Europe and North America learn to view the world through a relatively *individualistic* lens in which self-identity is based primarily on one's own attributes and achievements. People living in many Asian, African, and South American cultures tend to see the world through a more *collectivistic* framework in which personal identity is defined largely by the ties that bind one to the extended family and other social groups. Thus it stands to reason that if cultural socialization influences our schemas, and our schemas in turn influence how we encode and also reconstruct events, then people from different cultures may recall the events of their lives in somewhat distinct ways.

Let's consider an example: our earliest memories. In one study, Qi Wang (2001) asked over 200 college students from Harvard University and Beijing University to describe their earliest memories (Figure 7.29). He predicted and found that the Americans were more likely than their Chinese counterparts to recall events that focused on individual experiences and feelings, autonomy, and self-determination (e.g., "I was sorting baseball cards when I dropped them. As I reached down to get them, I knocked over a jug of iced tea."). In contrast, Chinese students were more likely than American students to recall memories that involved family or neighborhood activities and to mention other people (e.g., "Dad taught me ancient poems. It was always when he was washing vegetables that he would explain a poem to me.")

Wang also found that American college students dated their earliest personal memory back to the time when they were, on average, 3 ½ years old. Students in China, however, reported memories that on average dated to the time they were almost 4 years old. Several studies have obtained similar findings. Although the reason isn't clear, in part it may relate to American's greater tendency to report earliest memories of single, distinctive events that involved greater emotionality, whereas Chinese students were more likely than Americans to report more routine events that involved collective activity. Other researchers also have found cross-cultural differences in age of earliest memories. When Shelley MacDonald and coworkers (2000) studied New Zealand European, New Zealand Asian, New Zealand Maori, and Chinese adults, they found that Maori adults—whose traditional culture strongly values the past—recalled the earliest personal memories.

20. Illustrate how culture influences memory construction.

IN REVIEW

- *Our schemas may cause us to remember events not as they actually occurred but in ways that fit with our preexisting concepts about the world.*
- *At times we may recall information that never occurred. Schemas, spreading activation, and priming are some of the reasons why this occurs.*
- *Misinformation effects occur when our memory is distorted by misleading postevent information, and they often occur because of source confusion—our tendency to recall something or recognize it as familiar but to forget where we encountered it.*
- *Like adults, children experience misinformation effects. Vulnerability is greatest among younger children and when suggestive questions are asked repeatedly. Experts cannot reliably tell when children are reporting accurate versus sincerely believed false memories.*
- *Psychologists debate whether recovered memories of child abuse are accurate or whether they are "forgotten" through repression or other psychological processes. Concern about the possibility of false memory has led many experts to urge caution in unconditionally accepting the validity of recovered memories.*

MEMORY AND THE BRAIN

Where in your brain are memories located? How were they formed? The quest for answers has taken some remarkable twists. Psychologist Karl Lashley spent decades searching for the *engram*—the physical trace that presumably was stored in the brain when a memory was formed. Lashley (1950) trained animals to perform tasks, such as running mazes, and later removed or damaged (lesioned) specific regions of their cortex to see if they would forget how to perform the task. No matter what small area was lesioned, memories remained intact. Lashley never found the engram and concluded that a memory is stored throughout the brain.

In contrast, while performing brain surgery on patients who were under local anesthesia and fully conscious, Wilder Penfield (Penfield & Percot, 1963) seemed to trigger memories while electrically stimulating specific sites on the patients' cerebral cortex. One patient reported seeing the office in which she had worked a long time ago. Unfortunately, such instances were rare and probably involved inaccurate, reconstructed information, such as images of being in places where the patients had never been (Loftus & Loftus, 1980).

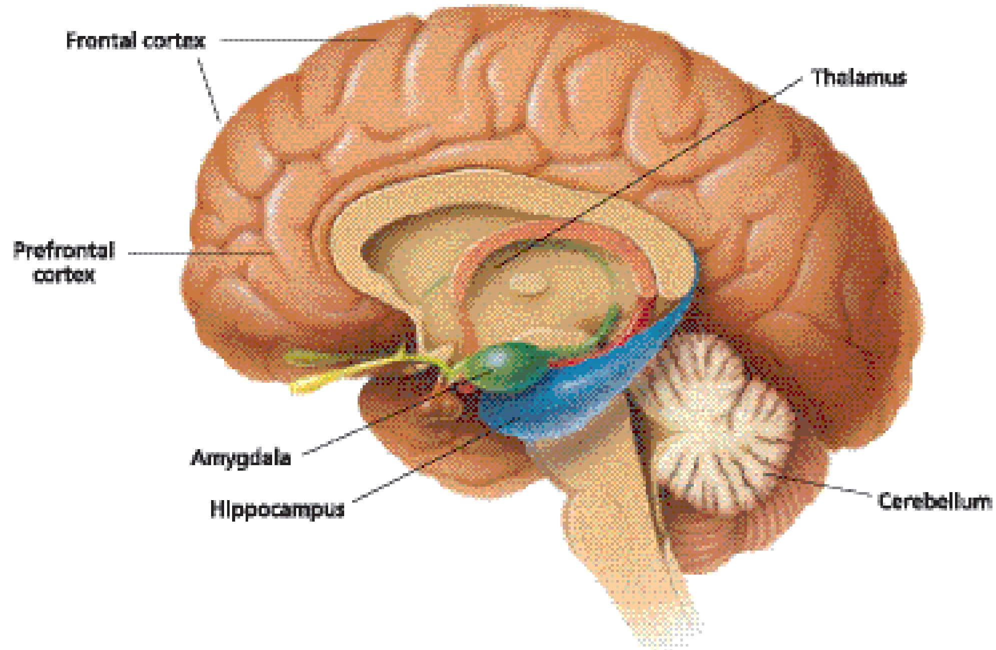
Perhaps most striking was James McConnell's (1962) discovery of "memory transfer." He classically conditioned flatworms to a light that was paired with electric shock, eventually causing the worms to contract to the light alone. Next he chopped them up and fed the RNA (ribonucleic acid) from their cells to untrained worms. Amazingly, the untrained worms showed some conditioning to the light, suggesting that RNA might be a "memory molecule" that stores experiences. Some scientists replicated these findings, but others were unable to, and McConnell eventually gave up on the idea (Rilling, 1996). Yet despite the inevitable "dead ends," scientists have learned a great deal about memory processes in the brain.

Where Are Memories Located?

To answer this question, scientists map the "geography" of memory. In *human lesion studies,* they examine memory loss caused by damage (e.g., from disease, accidents) to different brain regions. In *nonhuman animal lesion experiments,* researchers damage a specific part of the brain and observe how this affects memory. Finally, *brain-imaging studies* examine the healthy brain as participants perform various memory tasks. These lines of research increasingly reveal that memory involves

FIGURE 7.30

Many areas of the brain, such as the regions shown here, play key roles in memory.



many interacting brain regions (Nyberg et al., 2002). Figure 7.30 shows a few of these regions.

Sensory memory depends on our visual, auditory, and other sensory systems to detect stimulus information (e.g., the sounds of "Hi, my name is Carlos"), transform it into neural codes, and send it to the brain, where sensory areas of the cerebral cortex initially process it. As working memory becomes involved in different types of tasks—remembering a person's name and face or learning and rehearsing a concept in your textbook—a network of cortical areas located across different lobes of the brain becomes more active. Within this network, the frontal lobes—especially the prefrontal cortex—play a key role (Nyberg, et al., 2002). They seem to be particularly important in supporting executive functions, such as allocating attention to the other components of working memory. The frontal lobes generally become more active during tasks that place greater demands on working memory (Gabrielli et al., 1996).

Where are long-term memories formed and stored? Once again, multiple brain areas are involved, but the hippocampus and its adjacent areas appear to play an important role in encoding certain types of long-term memories (Rolls, 2000). Like H. M., many patients with extensive hippocampal damage retain the use of their short-term memory but cannot form new, explicit long-term declarative memories—memories for new personal experiences and facts. For example, one patient could recall the names of presidents elected before his brain injury occurred but not the names of presidents elected after his injury (Squire, 1987). The hippocampus does not seem to be the site where long-term declarative memories are permanently stored, which is why H. M. retained his long-term memories acquired earlier in life. Rather, it helps to gradually convert short-term memories into permanent ones.

According to one view, the diverse components of an experience—where something happened, what the scene or people looked like, sounds we heard, the meaning of events or information, and so on—are processed initially in different regions of the cortex and then gradually "bound" together in the hippocampus (Squire & Zola-Morgan 1991). *This hypothetical and gradual "binding" process is called* **memory consolidation.** Once a memory for a personal experience is consolidated, its various components appear to be stored across wide areas of the cortex, although we retrieve and reintegrate these components as a "unified memory." Semantic memories (factual information) also appear to be stored across wide-ranging areas of the brain. As John Gabrieli (1998, p. 94) notes, "knowledge in any domain [e.g., for pictures or words] . . . is distributed over a specific, but extensive, neural network that often extends over several lobes." Several brain regions, including portions of the prefrontal cortex and hippocampus, appear to be involved in consciously retrieving declarative memories (LePage et al., 1998; Tulving, 2002).

Although we have focused on the frontal lobes and hippocampus, memory formation also depends on other brain areas. For example, damage to the thalamus can produce severe amnesia, although we are not sure why this happens. In one famous case, a young U.S. Air Force technician named N. A. was injured in a freak accident (Squire, 1987). While his roommate was practicing thrusts with a miniature fencing foil, N. A. suddenly turned around in his seat and was stabbed through the right nostril, piercing his brain and damaging a portion of his thalamus. The damage permanently limited his ability to form new declarative memories. In many cases, thalamic damage also can cause permanent retrograde amnesia.

The amygdala appears to encode emotionally arousing aspects of events (Rodrigues et al., 2002). In laboratory experiments, most people remember emotionally arousing stimuli (e.g., film clips, slides) better than neutral ones. But damage to your amygdala would eliminate much of this "memory advantage" from arousing stimuli (LaBar & Phelps, 1998).

Finally, along with other parts of the brain, the cerebellum plays an important role in forming procedural memories. This helps to explain why H. M., whose cerebellum was not damaged by the operation, showed improved performance at various hand-eye coordination tasks (e.g., mirror-tracing) even though he was unable to consciously remember having performed the tasks.

Richard Thompson (1985) and coworkers have examined another type of procedural memory. Studying rabbits, they repeatedly paired a tone (CS) with a puff of air to the eyes (UCS), and soon the tone alone caused the rabbits to blink. As the rabbits learned this conditioned response, electrical recordings revealed increased electrical activity in the cerebellum. Later Thompson found that removing a tiny portion of the cerebellum completely abolished the memory for the *conditioned* eyeblink but did not affect the rabbits' general (unconditioned) eyeblink response. Similarly, eyeblink conditioning fails to work with human patients who have damaged cerebellums (Green & Woodruff, 2000).

How Are Memories Formed?

How does the nervous system form a memory? The answer appears to lie in chemical and physical changes that take place in the brain's neural circuitry.

Eric Kandel (2001) and his coworkers have studied a marine snail, *Aplysia californica*, for over 25 years—work for which Kandel received a Nobel Prize in 2000. *Aplysia* is no mental giant, but it can learn, form memories, and has only about 20,000 neurons (compared with our 100 billion) that are larger and easier to study than ours (Figure 7.31). For example, *Aplysia* retracts its gill slightly in self-defense when a breathing organ atop the gill is gently squirted with water. But if a squirt is paired with electric shock to its tail, *Aplysia* covers up its gill with a protective flap of skin. After repeated pairings, *Aplysia* acquires a classically conditioned response and will cover its gills with the protective flap when the water is squirted alone. In other words, *Aplysia* forms a simple procedural memory.

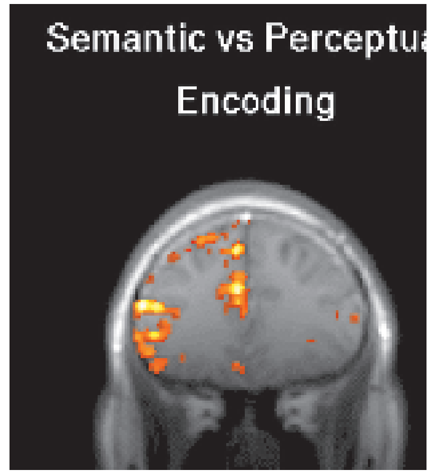


FIGURE 7.31

The marine snail Aplysia californica.

Kandel and his coworkers have traced the formation of this procedural memory to a series of biochemical events that occur between and within various sensory neurons and motor neurons. How long these events last seems to be one key in determining whether short-term memories become long-term ones. If a single shock is paired with the squirt of water, certain chemical reactions "shut off" after a brief period and no permanent memory is formed. But with repeated pairings, these chemical reactions persist and a long-term memory forms. Days later, a squirt of water will still trigger a conditioned response.

During the conditioning procedure, various sensory neurons become densely packed with neurotransmitter release points, and postsynaptic motor neurons (which cause the protective flap to retract) develop more receptor sites. These structural changes result in greater ease of synaptic transmission that may be the basis for memory consolidation (Abel & Kandel, 1998).

A different line of research, involving rats and other species with more complex nervous systems,

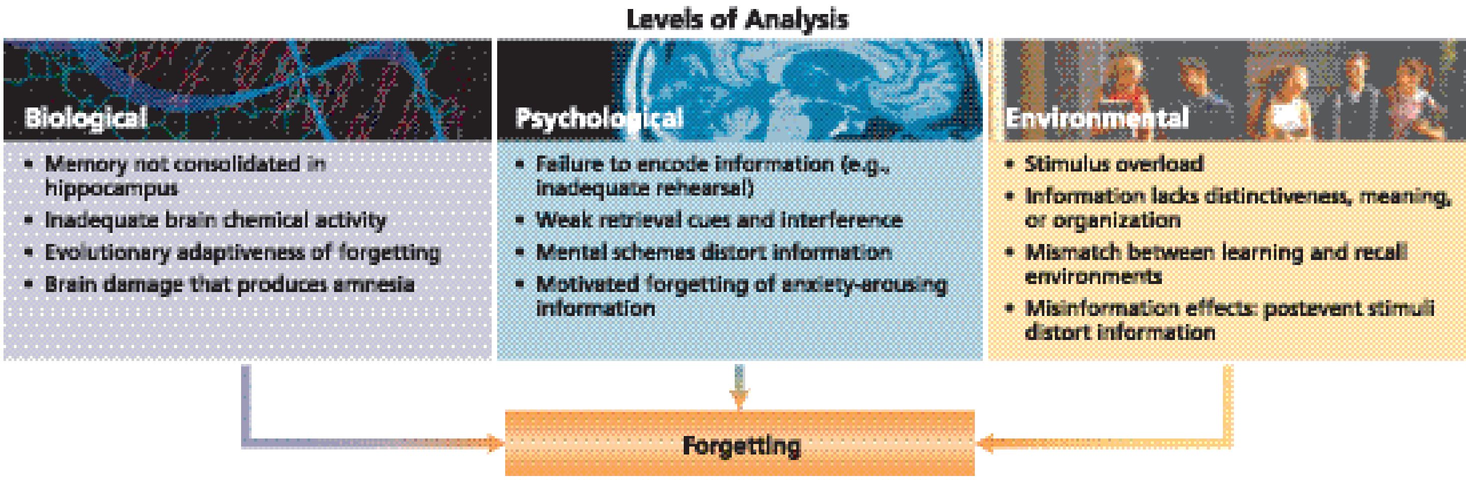


FIGURE 7.32

Understanding behavior: some factors that contribute to forgetting.

supports this hypothesis. Here, researchers try to mimic (albeit very crudely) a process of long-term memory formation by stimulating specific neural pathways with rapid bursts of electricity (say, 100 impulses per second for several seconds). They find that once this rapid stimulation ends, the neural pathway becomes stronger—synaptic connections are activated more easily—for days or even weeks (Martinez et al., 1998). *This enduring increase in synaptic strength is called* **long-term potentiation (LTP)**. LTP has been studied most extensively in regions of the hippocampus where neurons send and receive glutamate, the most abundant neurotransmitter in the brain.

For LTP to occur, certain biochemical events must take place inside and between these neurons. Administering drugs that inhibit these events will block LTP. Moreover, mice can be genetically bred to be deficient in certain proteins required for LTP. These mice not only have impaired long-term potentiation but also display memory deficits on a variety of learning tasks (Rotenberg et al., 2000).

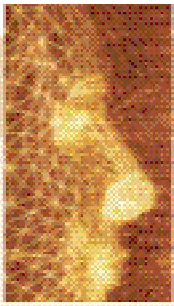
How, then, does LTP occur? At least in some cases, it appears that when neural pathways are sufficiently stimulated, the postsynaptic neurons alter their structure so that they become more responsive to glutamate. For example, postsynaptic neurons may change the shape of some receptor sites, or they may increase the number of receptor sites by developing additional tiny branches (spines) on their dendrites. This means that in the future, presynaptic neurons will not need to release as much glutamate in order to stimulate postsynaptic neurons to fire. In sum, the formation of a long-term memory seems to involve long-lasting changes in synaptic efficiency that result from new or enhanced connections between presynaptic and postsynaptic neurons (Kandell, 2001).

21. Describe brain structures involved in memory and how changes in neural circuitry may underlie memory formation.

In closing, we hope that this chapter has piqued your interest in understanding why we remember, forget, and sometimes misremember. Figure 7.32 summarizes some factors involved in forgetting and memory distortion. We also hope that the chapter has applied value for you. Following the "In Review" summary, our "Applying Psychological Science" feature summarizes some ways to enhance your own memory and academic learning.

IN REVIEW

- *Memory involves numerous interacting brain regions. Sensory memory depends on input from our sensory systems and sensory areas of the cortex that initially process this information.*
- *Working memory involves a network of brain regions. The frontal lobes play a key role in performing the executive functions of working memory.*
- *The hippocampus helps consolidate long-term declarative memories. The cerebral cortex stores declarative memories across distributed sites.*
- *The amygdala encodes emotionally arousing aspects of events, and the cerebellum helps form procedural memories. Damage to the thalamus can produce severe amnesia.*
- *Research with sea snails and studies of long-term potentiation in other species indicate that as memories form, complex chemical and structural changes occur in neurons that enhance synaptic efficiency.*



APPLYING PSYCHOLOGICAL SCIENCE

IMPROVING MEMORY AND ACADEMIC LEARNING

There are no "magical" or effortless way to enhance memory, but psychological research offers many principles that you can put to your advantage. Memory enhancement strategies fall into three broad categories:

- *external aids,* such as shopping lists, notes, and appointment calendars;
- *general memory strategies,* such as organizing and rehearsing information; and
- *formal mnemonic techniques,* such as acronyms, the method of loci, and other systems that take training to be used effectively.

Memory researchers strongly recommend using external aids and general strategies to enhance memory (Park et al., 1990). Of course, during "closed-book" college exams, external aids may land you in the Dean's office! Here, the following principles can enhance memory.

Use Elaborative Rehearsal to Process Information Deeply

Elaborative rehearsal—focusing on the meaning of information—enhances deep processing and memory (Benjamin & Bjork, 2000). Put simply, *if you are trying to commit information to memory, make sure that you understand what it means.* You may think we're daffy for stating such an obvious point, but many students try to learn material by rote memorization rather than by making an effort to understand it. Students who find material confusing sometimes try to bypass their confusion with rote memorization —an approach that often fails—whereas they should be seeking assistance to have the material explained. The learning objectives and practice tests that appear in the Online Learning Center (OLC) can help you process the course material more deeply by helping you focus on and think about key points.

Link New Information to Examples and Items Already in Memory

Once you understand the material, process it more deeply by associating it with information you already know. This creates memory "hooks" onto which you can hang new information. Because you already have many memorable life experiences, *make new information personally meaningful* by relating it to your life.

Pay attention to examples, even if they are unrelated to your own experiences. In one study, participants read a 32-paragraph essay about a fictitious African nation. Each paragraph presented a topic sentence stating a main theme along with zero, one, two, or three examples illustrating that theme. The greater the number of examples, the better the participants recalled the themes (Palmere et al., 1983).

Organize Information

Organizing information keeps you actively thinking about the material and makes it more meaningful. Before reading a chapter, look at its outline to determine how the material is logically developed. When studying, take notes from a chapter and use outlining to organize the information. This hierarchical structure forces you to arrange main ideas above subordinate ones and becomes an additional retrieval cue that facilitates recall (Bower et al., 1969).

Use Imagery

As dual coding theory predicts, images provide a splendid second "cognitive hook" on which to hang and retrieve information (Paivio et al., 2000). Instead of writing down customers' orders, some restaurant waiters and waitresses form images, such as visualizing a man who has ordered a margarita turning light green. As one waitress remarked, "After a while, customers start looking like drinks" (Bennett, 1983, p. 165). Be creative. For example, to help you remember that flashbulb memories often are less accurate than people think, imagine a camera flashbulb with a big red X through it.

Overlearn the Material

Overlearning *refers to continued rehearsal past the point of initial learning, and it significantly improves performance on memory tasks* (Driskell et al., 1992). Moreover, much of this memory boost persists for a long time after overlearning ends. In short, just as elite athletes keep practicing their already honed skills and professional actors continue to rehearse scripts they already know, keep studying material after you have first learned it (Noice & Noice, 2002a).

Distribute Learning Over Time and Test Yourself

You have finished the readings and organized your notes for an upcoming test. Now it's time to study and review. Are you better off with *massed practice,* a marathon session of highly concentrated learning, or with *distributed practice,* several shorter sessions spread out over a few days? Research indicates that you will retain more information with distributed practice, and that periodically testing yourself on the material before an exam can further enhance learning (Cull, 2000). Distributed practice can reduce fatigue and anxiety, both of which impair learning.

Continued

Testing yourself ahead of time (e.g., using practice items, if available, or questions such as those in the margin of this textbook) helps you to further rehearse the material and to identify content that you don't understand.

Minimize Interference

Distributed practice is effective because rest periods between study sessions reduce interference from competing material. However, when you need to study for several exams on the same or consecutive days, there really are few rest periods. There is no simple solution to this problem. Suppose you have a psychology exam on Thursday and a sociology exam on Friday. Try to arrange several sessions of distributed practice for each exam over the preceding week. On Wednesday, limit your studying to psychology if possible. Once your psychology exam is over, turn your attention to your second test. This way, the final study period for each course will occur as close as possible to test time and minimize interference from other cognitive activities.

Studying before you go to sleep may enhance retention by temporarily minimizing interference, but if you are carrying a typical college course load, you will likely have to contend with interference much of the time. This is why overlearning is so important, and why you are advised to study the material beyond the point where you feel you have learned it.

22. Identify practical principles for enhancing memory.

What Do You Think?

WOULD PERFECT MEMORY BE A GIFT OR A CURSE?

No doubt, perfect memory would have advantages, but were you able to think of any liabilities? Russian newspaper reporter S. V. Shereshevski—arguably the most famous mnemonist in history—had a remarkable capacity to remember numbers, poems in foreign languages, complex mathematical formulas, nonsense syllables, and sounds. Psychologist Aleksandr Luria (1968), who studied "S." for decades, describes how S. was tyrannized by his seeming inability to forget meaningless information. Almost any stimulus might unleash a flood of trivial memories that dominated S.'s consciousness and made it difficult for him to concentrate or think abstractly.

S.'s experience may have been atypical, but perfect memory could indeed clutter up our thinking with trivial information. Moreover, perfect memory would deprive us of one of life's blessings: the ability to forget unpleasant experiences from our past. As we will illustrate later in this chapter, *imperfect* memory allows us to view our past through slightly rosy glasses (Bahrick, et al., 1996).

Would a perfect memory help you perform better on exams? On test questions calling only for definitions, formulas, or facts, probably so. But on questions asking you to apply concepts, synthesize ideas, analyze issues, and so forth, perfect memory might be of little benefit unless you also understood the material. In his graduate school classes,

> Rajan had a tendency to try to commit the reading assignments to memory and reproduce them on tests. The strategy . . . is counterproductive in graduate courses where students are asked to apply their knowledge and understanding to new situations . . . . When taking tests, Rajan would write furiously . . . in hopes that the correct answer was somewhere in his response. . . . As he progressed in our graduate program, he tended to rely less on the strategy of memorizing everything and more on trying to understand and organize the information. (Thompson et al.,1993, p. 15).

Rajan's extraordinary memory for numbers did not extend to reading or visual tasks, but even if yours did, it still might tempt you to focus too heavily on sheer memorization and cause you to neglect paying attention to the meaning of the material. In sum, although imperfect memory can be frustrating and cause important problems (as when eyewitnesses identify the wrong suspect), we should also appreciate how our memory system is balanced between the adaptiveness of remembering and the benefits of forgetting.

(By the way, in case you're curious, the current record for recalling pi is 42,195 digits. In 1999, Sim Pohann of Malaysia recalled 67,053 digits, but alas, he made 15 errors. To put this feat in perspective, imagine the next 12 pages of this textbook filled up with nothing but numbers!) ■

IS IT REALLY ON THE TIP OF YOUR TONGUE?

Please try to answer the following questions:

- What is the name of the only kind of living reptile that flies?

- What is the name of the only type of cat native to Australia?
- What is the name of the planet Mercury's moon?

Did you feel like the answer to any of these questions was on the tip of your tongue? If you didn't, that's OK. We just want to illustrate some of the questions that Bennett Schwartz (1998) asked college students in a clever TOT study.

Schwartz asked students 100 questions, but 20 of them—like the ones above—were unanswerable (e.g., Mercury has no moon). If there was no correct answer, then students could not have a true retrieval problem, because there was no stored information to retrieve. Yet nearly one fifth of the time, students felt that the answer was on the tip of their tongue when they were contemplating these questions. Schwartz obtained similar findings in another experiment.

Schwartz calls these experiences "illusory TOT states": People feel that the answer is on the tip of their tongue when it can't possibly be. Illusory TOT states raise complex issues about the nature of memory, but for the moment, let's just focus on a simple point. Sometimes, when we feel that an answer is on the tip of our tongue, the cause may not be an inability to retrieve information stored in long-term memory, but rather it may be that the information never got stored in the first place. In other words, whether due to encoding failure (we've encountered the information but didn't process it adequately) or some other reason, we really may not know the answer, although we think we do. This may help explain why we never resolve some of our TOT states and often turn to other people or reference books to help find an answer.

If you're curious, try reading the three questions above to several friends (give them time to think about each question). Don't expect to trigger a lot of illusory TOT states, but even eliciting one or two would provide an interesting demonstration. Afterwards, be sure to let them know that the questions are unanswerable (so they won't keep thinking about them!) and explain the purpose of the exercise. ■

KEY TERMS AND CONCEPTS

Each term has been boldfaced and defined in the textbook on the page indicated in parentheses.

anterograde amnesia (p. 00)
associative network (p. 00)
chunking (p. 00)
context-dependent memory (p. 00)
decay theory (p. 00)
declarative memory (p. 00)
dual coding theory (p. 00)
elaborative rehearsal (p. 00)
encoding (p. 00)
encoding specificity principle (p. 00)
episodic memory (p. 00)
explicit memory (p. 00)
flashbulb memories (p. 00)
implicit memory (p. 00)
infantile amnesia (p. 00)
levels of processing (p. 00)
long-term memory (p. 00)
long-term potentiation (p. 00)
maintenance rehearsal (p. 00)
memory (p. 00)
memory codes (p. 00)
memory consolidation (p. 00)
method of loci (p. 00)
misinformation effect (p. 00)
mnemonic device (p. 00)
mnemonist (memorist) p. 00)
mood-congruent recall (p. 00)
neural network (p. 00)
overlearning (p. 00)
priming (p. 00)
proactive interference (p. 00)
procedural (nondeclarative) memory (p. 00)
prospective memory (p. 00)
repression (p. 00)
retrieval (p. 00)
retrieval cue (p. 00)
retroactive interference (p. 00)
retrograde amnesia (p. 00)
schema (p. 00)
semantic memory (p. 00)
sensory memory (p. 00)
serial position effect (p. 00)
short-term memory (p. 00)
source confusion (p. 00)
state-dependent memory (p. 00)
storage (p. 00)
tip-of-the-tongue (TOT) state (p. 00)
working memory (p. 00)