SOME QUESTIONS WE WILL CONSIDER

- Why can we remember a telephone number long enough to place a call, but then we forget it almost immediately? (138)
- How is memory involved in processes such as doing a math problem? (143)
- Do we use the same memory system to remember things we have seen and things we have heard? (145)

So much has been written about memory—the advantages of having a good memory, the pitfalls of forgetting, or in the worst case, losing one's ability to remember—that it may hardly seem necessary to read a cognitive psychology textbook to understand what memory is. But as you will see over the next four chapters, "memory" is not just one thing. Memory, like attention, comes in many forms. One of the purposes of this chapter and the next is to introduce the different types of memory, describing the properties of each type and the mechanisms responsible for them. Let's begin with two definitions of memory:

- **Memory** is the process involved in retaining, retrieving, and using information about stimuli, images, events, ideas, and skills after the original information is no longer present.
- Memory is active any time some past experience has an effect on the way you think or behave now or in the future (Joordens, 2011).

From these definitions, it is clear that memory has to do with the past affecting the present, and possibly the future. But while these definitions are correct, we need to consider the various ways in which the past can affect the present to really understand what memory is. When we do this, we will see that there are many different kinds of memory. With apologies to the English poet Elizabeth Barrett Browning, whose famous poem to her husband begins "How do I love thee, let me count the ways," let's consider a woman we'll call Christine as she describes incidents from her life that illustrate a related question: "How do I *remember* thee, let me count the ways" (see **Figure 5.1**).

> My first memory of you was brief and dramatic. It was the Fourth of July, and everyone was looking up at the sky to see the fireworks. But what I saw was your face—illuminated

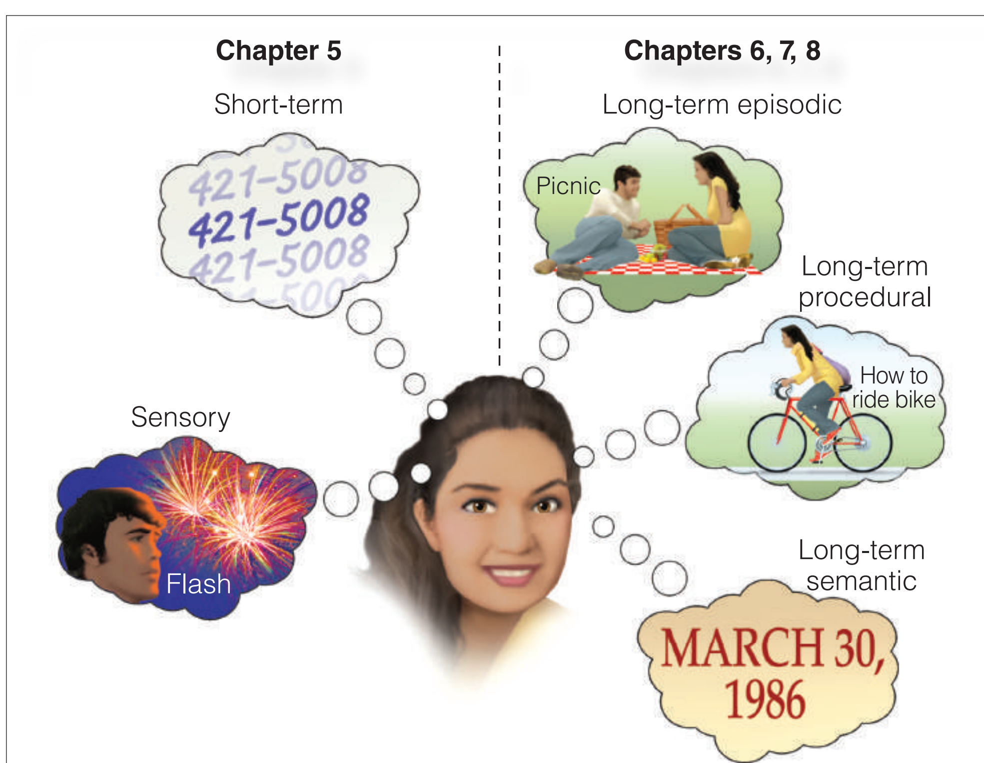


Figure 5.1 Five types of memory described by Christine. See text for details.

> for just a moment by a flash, and then there was darkness. But even in the darkness I held your image in my mind for a moment.

When something is presented briefly, such as a face illuminated by a flash, your perception continues for a fraction of a second in the dark. This brief persistence of the image, which is one of the things that makes it possible to perceive movies, is called *sensory memory*.

> Luckily, I had the presence of mind to "accidentally" meet you later so we could exchange phone numbers. Unfortunately, I didn't have my cell phone with me or anything to write with, so I had to keep repeating your number over and over until I could write it down.

Information that stays in our memory for brief periods, about 10 to 15 seconds if we don't repeat it over and over as Christine did, is *short-term memory* or *working memory*.

> And the rest is history, because I have countless memories of all the things we have done. I especially remember that crisp fall day when we went bike riding to that place in the woods where we had a picnic.

Long-term memory is responsible for storing information for long periods of time—which can extend from minutes to a lifetime. Long-term memories of *experiences* from the past, like the picnic, are *episodic memories*. The ability to ride a bicycle, or do any of the other things that involve muscle coordination, is a type of long-term memory called *procedural memory*.

> I must admit, however, that as much as I remember many of the things we have done, I have a hard time remembering the address of the first apartment we lived in, although, luckily for me, I do remember your birthday.

Another type of long-term memory is *semantic memory*—memories of facts such as an address or a birthday or the names of different objects ("that's a bicycle").

We will describe sensory memory and short-term memory in this chapter, we will compare short-term and long-term memory at the beginning of Chapter 6, and then spend the rest of Chapter 6 plus Chapters 7 and 8 on long-term memory. We will see that although people often mistakenly use the term "short-term memory" to refer to memory for events that happened minutes, hours, or even days ago, it is actually much briefer. In Chapter 6 we will note that this misconception about the length of short-term memory is reflected in how memory loss is described in movies. People also often underestimate the importance of short-term memory. When I ask my students to create a "top 10" list of what they use memory for, most of the items come under the heading of long-term memory. The four top items on their list are the following:

Material for exams

Their daily schedule

Names

Directions to places

Your list may be different, but items from short-term memory rarely make the list, especially since the Internet and cell phones make it less necessary to repeat phone numbers over and over to keep them alive in memory. So what is the purpose of sensory and short-term memory?

Sensory memory is important when we go to the movies (more on that soon), but the main reason for discussing sensory memory is to demonstrate an ingenious procedure for measuring how much information we can take in immediately, and how much of that information remains half a second later.

The purpose of short-term memory will become clearer as we describe its characteristics, but stop for a moment and answer this question: What are you aware of right now? Some material you are reading about memory? Your surroundings? Noise in the background? Whatever your answer, you are describing what is in short-term memory. Everything you know or think about at each moment in time is in short-term memory. Thirty seconds from now your "old" short-term memories may have faded, but new ones will have taken over. Your "to do" list in long-term memory may be important, but as you are doing each of the things on your list, you are constantly using your short-term memory. As you will see in this chapter, short-term memory may be short in duration, but it looms large in importance.

We begin our description of sensory and short-term memory by describing an early and influential model of memory called the *modal model*, which places sensory and short-term memory at the beginning of the process of memory.

The Modal Model of Memory

Remember Donald Broadbent's (1958) filter model of attention, which introduced the flow chart that helped usher in the information processing approach to cognition (Chapter 1, page 14; Chapter 4, page 95). Ten years after Broadbent introduced his flow diagram for attention, Richard Atkinson and Richard Shiffrin (1968) introduced the flow diagram for memory shown in **Figure 5.2**, which is called the **modal model of memory**. This model proposed three types of memory:

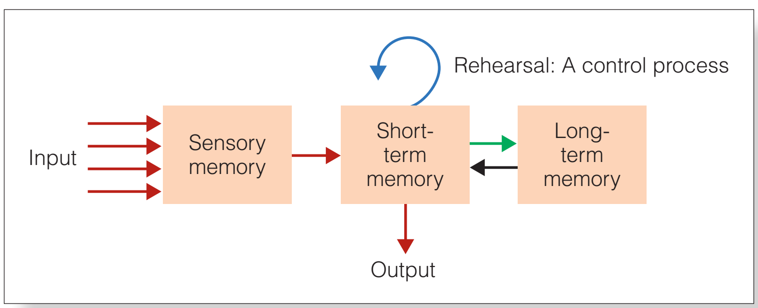


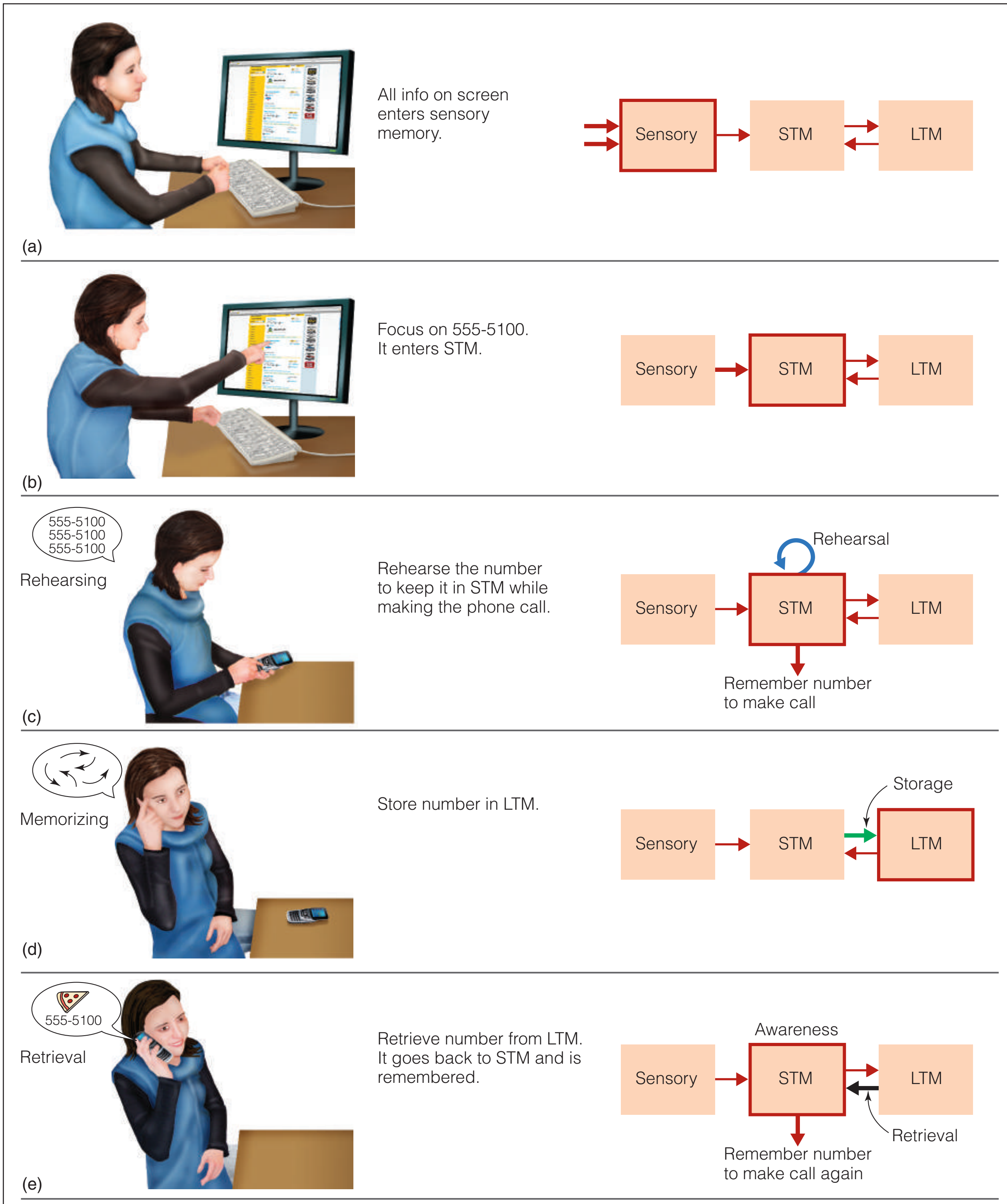
Figure 5.2 Flow diagram for Atkinson and Shiffrin's (1968) modal model of memory. This model, which is described in the text, is called the modal model because it contains features of many of the memory models that were being proposed in the 1960s.

1. *Sensory memory* is an initial stage that holds all incoming information for seconds or fractions of a second.
2. Short-term memory (STM) holds five to seven items for about 15 to 20 seconds. We will describe the characteristics of short-term memory in this chapter.
3. Long-term memory (LTM) can hold a large amount of information for years or even decades. We will describe long-term memory in Chapters 6, 7, and 8.

The types of memory listed above, each of which is indicated by a box in the model, are called the **structural features** of the model. As we will see, the short-term memory and long-term memory boxes in this diagram were expanded by later researchers, who modified the model to distinguish between the different types of short- and long-term memories. But for now, we take this simpler modal model as our starting point because it illustrates important principles about how different types of memory operate and interact.

Atkinson and Shiffrin also proposed **control processes**, which are dynamic processes associated with the structural features that can be controlled by the person and may differ from one task to another. An example of a control process that operates on short-term memory is **rehearsal**—repeating a stimulus over and over, as you might repeat a telephone number in order to hold it in your mind after looking it up on the Internet. Rehearsal is symbolized by the blue arrow in Figure 5.2. Other examples of control processes are (1) strategies you might use to help make a stimulus more memorable, such as relating the digits in a phone number to a familiar date in history, and (2) strategies of attention that help you focus on information that is particularly important or interesting.

To illustrate how the structural features and control processes operate, let's consider what happens as Rachel looks up the number for Mineo's Pizza on the Internet (**Figure 5.3**). When she first looks at the screen, all of the information that enters her eyes is registered in sensory memory (**Figure 5.3a**). Rachel uses the control process of selective attention to focus on the number for Mineo's, so the number enters her short-term memory (**Figure 5.3b**), and she uses the control process of rehearsal to keep it there (**Figure 5.3c**).



➤ **Figure 5.3** What happens in different parts of Rachel's memory as she is (a, b) looking up the phone number, (c) calling the pizza shop, and (d) memorizing the number. A few days later, (e) she retrieves the number from long-term memory to order pizza again. The parts of the modal model that are outlined in red indicate which processes are activated for each action that Rachel takes.

Rachel knows she will want to use the number again later, so she decides that in addition to storing the number in her cell phone, she is going to memorize the number so it will also be stored in her mind. The process she uses to memorize the number, which involves control processes that we will discuss in Chapter 6, transfers the number into long-term memory, where it is stored (**Figure 5.3d**). The process of storing the number in long-term memory is called *encoding*. A few days later, when Rachel's urge for pizza returns, she remembers the number. This process of remembering information that is stored in long-term memory is called *retrieval* (**Figure 5.3e**).

One thing that becomes apparent from our example is that the components of memory do not act in isolation. Thus, the phone number is first stored in Rachel's STM, but because information is easily lost from STM (as when you forget a phone number), Rachel transfers the phone number into LTM (green arrow), where it is held until she needs it later. When she then remembers the phone number later, it is returned to STM (black arrow), and Rachel becomes aware of the phone number. We will now consider each component of the model, beginning with sensory memory.

Sensory Memory

Sensory memory is the retention, for brief periods of time, of the effects of sensory stimulation. We can demonstrate this brief retention for the effects of visual stimulation with two familiar examples: the trail left by a moving sparkler and the experience of seeing a film.

The Sparkler's Trail and the Projector's Shutter

It is dark out on the Fourth of July, and you put a match to the tip of a sparkler. As sparks begin radiating from the tip, you sweep the sparkler through the air, creating a trail of light (**Figure 5.4a**). Although it appears that this trail is created by light left by the sparkler as you wave it through the air, there is, in fact, no light along this trail. The lighted trail is a creation of your mind, which retains a perception of the sparkler's light for a fraction of a second (**Figure 5.4b**). This retention of the perception of light in your mind is called the *persistence of vision*.

Persistence of vision is the continued perception of a visual stimulus even after it is no longer present. This persistence lasts for only a fraction of a second, so it isn't obvious in everyday experience when objects are present for long periods. However, the persistence of vision effect is noticeable for brief stimuli, like the moving sparkler or rapidly flashed pictures in a movie theater.

While you are watching a movie, you may see actions moving smoothly across the screen, but what is actually projected is quite different. First, a single film frame is positioned in front of the projector lens, and when the projector's shutter opens and closes, the image on the film frame flashes onto the screen. When the shutter is closed, the film moves on to the next frame, and during that time the screen is dark. When the next frame has arrived in front of the lens, the shutter opens and closes again, flashing the next image onto the screen. This process is repeated rapidly, 24 times per second, with 24 still images flashed on the screen every second and each image followed by a brief period of darkness (see **Table 5.1**). (Note that some filmmakers are now beginning to experiment with higher frame rates, as in Peter Jackson's *The Hobbit: An Unexpected Journey* (2012), shot at 48 frames per second, and Ang Lee's *Billy Lynn's Long Halftime Walk* (2016), shot at 120 frames per second.) A person viewing the film doesn't see the dark intervals between the images because the persistence of vision fills in the darkness by retaining the image of the previous frame.

➤ **Figure 5.4** (a) A sparkler can cause a trail of light when it is moved rapidly. (b) This trail occurs because the perception of the light is briefly held in the mind.

TABLE 5.1
Persistence of Vision in Film*

What Happens?	What Is on the Screen?	What Do You Perceive?
Film frame 1 is projected.	Picture 1	Picture 1
Shutter closes and film moves to the next frame.	Darkness	Picture 1 (persistence of vision)
Shutter opens and film frame 2 is projected.	Picture 2	Picture 2

*The sequence indicated here is for movies projected using traditional film. Newer digital movie technologies are based on information stored on discs.

Sperling's Experiment: Measuring the Capacity and Duration of the Sensory Store

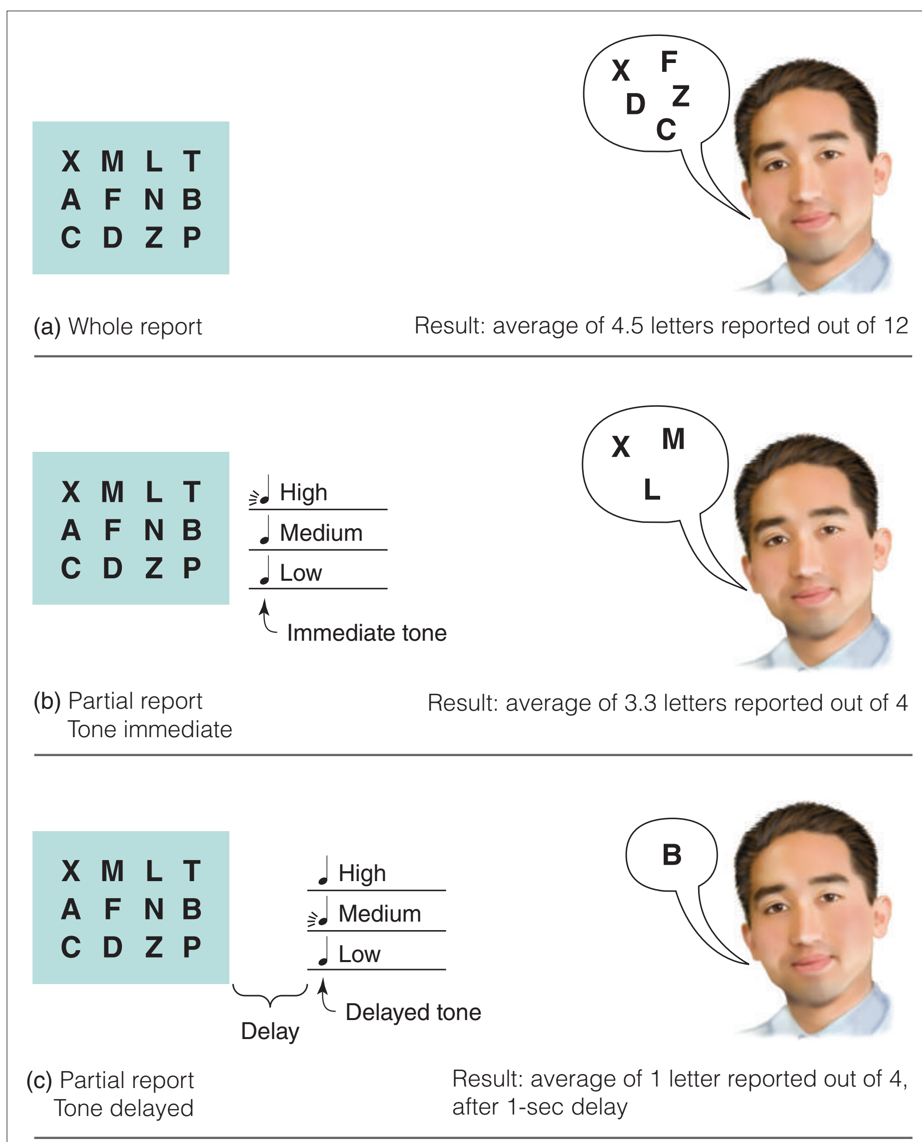
The persistence of vision effect that adds a trail to our perception of moving sparklers and fills in the dark spaces between frames in a film has been known since the early days of psychology (Boring, 1942). But George Sperling (1960) wondered how much *information* people can take in from briefly presented stimuli. He determined this in a famous experiment in which he flashed an array of letters, like the one in **Figure 5.5a**, on the screen for 50 milliseconds (50/1000 second) and asked his participants to report as many of the letters as possible. This part of the experiment used the **whole report method**; that is, participants were asked to report as many letters as possible from the entire 12-letter display. Given this task, they were able to report an average of 4.5 out of the 12 letters.

At this point, Sperling could have concluded that because the exposure was brief, participants saw only an average of 4.5 of the 12 letters. However, some of the participants in Sperling's experiment reported that they had seen all the letters, but that their perception had faded rapidly as they were reporting the letters, so by the time they had reported 4 or 5 letters, they could no longer see or remember the other letters.

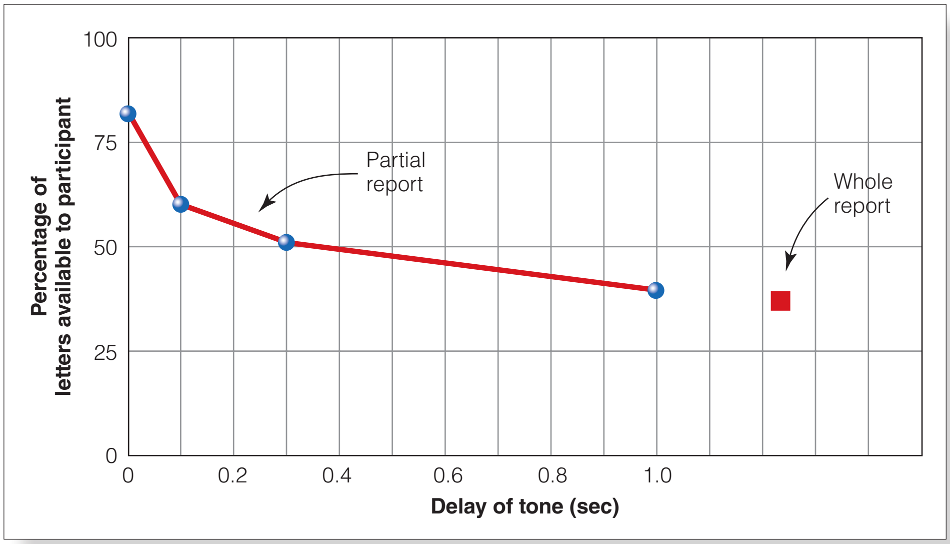
Sperling reasoned that if participants couldn't report the 12-letter display because of fading, perhaps they would do better if they were told to just report the letters in a single 4-letter row. Sperling devised the **partial report method** to test this idea. Participants saw the 12-letter display for 50 ms, as before, but immediately after it was flashed, they heard a tone that told them which row of the matrix to report. A high-pitched tone indicated the top row; a medium-pitch indicated the middle row; and a low-pitch indicated the bottom row (**Figure 5.5b**).

Because the tones were presented immediately *after* the letters were turned off, the participant's attention was directed not to the actual letters, which were no longer present, but to whatever trace remained in the participant's mind after the letters were turned off. When the participants focused their attention on one of the rows, they correctly reported an average of about 3.3 of the 4 letters (82 percent) in that row. Because this occurred no matter which row they were reporting, Sperling concluded that immediately after the 12-letter display was presented, participants saw an average of 82 percent of all of the letters but were not able to report all of these letters because they rapidly faded as the initial letters were being reported.

Sperling then did an additional experiment to determine the time course of this fading. For this experiment, Sperling devised a **delayed partial report method** in which the letters were flashed on and off and then the cue tone was presented after a short delay (**Figure 5.5c**). The result of the delayed partial report experiments was that when the cue



➤ Figure 5.5 Procedure for three of Sperling's (1960) experiments. (a) Whole report method: Person saw all 12 letters at once for 50 ms and reported as many as he or she could remember. (b) Partial report: Person saw all 12 letters, as before, but immediately after they were turned off, a tone indicated which row the person was to report. (c) Delayed partial report: Same as (b), but with a short delay between extinguishing the letters and presentation of the tone.



➤ **Figure 5.6** Results of Sperling's (1960) partial report experiments. The decrease in performance is due to the rapid decay of iconic memory (sensory memory in the modal model).

tones were delayed for 1 second after the flash, participants were able to report only slightly more than 1 letter in a row. **Figure 5.6** plots this result, showing the percentage of letters available to the participants from the entire display as a function of time following presentation of the display. This graph indicates that immediately after a stimulus is presented, all or most of the stimulus is available for perception. This is sensory memory. Then, over the next second, sensory memory fades.

Sperling concluded from these results that a short-lived sensory memory registers all or most of the information that hits our visual receptors, but that this information **decays** within less than a second. This brief sensory memory for visual stimuli, called **iconic memory** or the **visual icon** (icon means "image"), corresponds to the sensory memory stage of Atkinson and Shiffrin's modal model. Other research using auditory stimuli has shown that sounds also persist in the mind. This persistence of sound, called **echoic memory**, lasts for a few seconds after presentation of the original stimulus (Darwin et al., 1972). An example of echoic memory is when you hear someone say something, but you don't understand at first and say "What?" But even before the person can repeat what was said, you "hear" it in your mind. If that has happened to you, you've experienced echoic memory. In the next section, we consider the second stage of the modal model, short-term memory, which also holds information briefly, but for much longer than sensory memory.

Short-Term Memory: Storage

We saw in the preceding section that although sensory memory fades rapidly, Sperling's participants could report some of the letters. These letters are the part of the stimuli that has moved on to short-term memory in the flow diagram in Figure 5.2. **Short-term memory (STM)** is the system involved in storing small amounts of information for a brief period of time (Baddeley et al., 2009). Thus, whatever you are thinking about right now, or remember from what you have just read, is in your short-term memory. As we will see below, most of this information is eventually lost, and only some of it reaches the more permanent store of long-term memory (LTM).

Because of the brief duration of STM, it is easy to downplay its importance compared to LTM, but, as we will see, STM is responsible for a great deal of our mental life.

Everything we think about or know at a particular moment in time involves STM because short-term memory is our window on the present. (Remember from Figure 5.3e that Rachel became aware of the pizzeria's phone number by transferring it from LTM, where it was stored, back into her STM.) We will now describe some early research on STM that focused on answering the following two questions: (1) What is the duration of STM? (2) What is the capacity of STM? These questions were answered in experiments that used the method of *recall* to test memory.

METHOD Recall

Most of the experiments we will be describing in this chapter involve **recall**, in which participants are presented with stimuli and then, after a delay, are asked to report back as many of the stimuli as possible. Memory performance can be measured as a percentage of the stimuli that are remembered. (For example, studying a list of 10 words and later recalling 3 of them is 30 percent recall.) Participants' responses can also be analyzed to determine whether there is a pattern to the way items are recalled. (For example, if participants are given a list consisting of types of fruits and models of cars, their recall can be analyzed to determine whether they grouped cars together and fruits together as they were recalling them.) Recall is also involved when a person is asked to recollect life events, such as graduating from high school, or to recall facts they have learned, such as the capital of Nebraska.

What Is the Duration of Short-Term Memory?

One of the major misconceptions about short-term memory is that it lasts for a relatively long time. It is not uncommon for people to refer to events they remember from a few days or weeks ago as being remembered from short-term memory. However, short-term memory, as conceived by cognitive psychologists, lasts 15 to 20 seconds or less. This was demonstrated by John Brown (1958) in England and Lloyd Peterson and Margaret Peterson (1959) in the United States, who used the method of recall to determine the duration of STM. Peterson and Peterson presented participants with three letters, such as FZL or BHM, followed by a number, such as 403. Participants were instructed to begin counting backwards by threes from that number. This was done to keep participants from rehearsing the letters. After intervals ranging from 3 to 18 seconds, participants were asked to recall the three letters. Participants correctly recalled about 80 percent of the three letter groups when they had counted for only 3 seconds, but recalled only about 12 percent of the groups after counting for 18 seconds. Results such as this have led to the conclusion that the effective duration of STM (when rehearsal is prevented, as occurred when counting backwards) is about 15 to 20 seconds or less (Zhang & Luck, 2009).

How Many *Items* Can Be Held in Short-Term Memory?

Not only is information lost rapidly from STM, but there is a limit to how much information can be held there. As we will see, estimates for how many items can be held in STM range from four to nine.

Digit Span One measure of the capacity of STM is provided by the **digit span**—the number of digits a person can remember. You can determine your digit span by doing the following demonstration.

DEMONSTRATION Digit Span

Using an index card or piece of paper, cover all of the numbers below. Move the card down to uncover the first string of numbers. Read the first set of numbers once, cover it up, and then write the numbers down in the correct order. Then move the card to the next string, and repeat this procedure until you begin making errors. The longest string you are able to reproduce without error is your digit span.

2 1 4 9

3 9 6 7 8

6 4 9 7 8 4

7 3 8 2 0 1 5

8 4 2 6 4 1 3 2

4 8 2 3 9 2 8 0 7

5 8 5 2 9 8 4 6 3 7

If you succeeded in remembering the longest string of digits, you have a digit span of 10 or perhaps more.

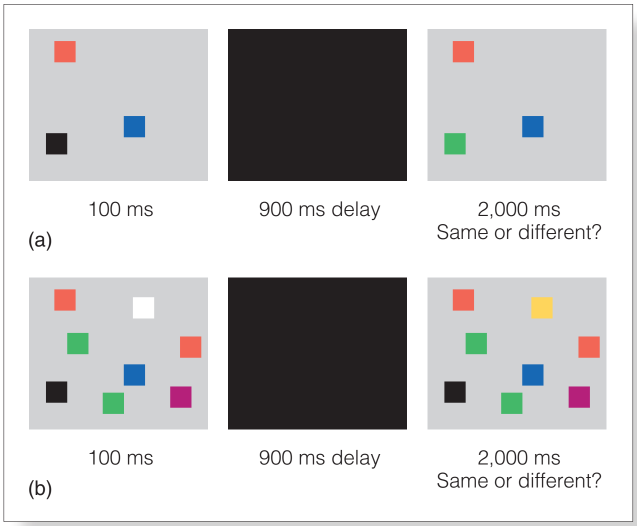
According to measurements of digit span, the average capacity of STM is about five to nine items—about the length of a phone number. This idea that the limit of STM is somewhere between five and nine was suggested by George Miller (1956), who summarized the evidence for this limit in his paper "The Magical Number Seven, Plus or Minus Two," described in Chapter 1 (page 15).

Change Detection More recent measures of STM capacity have set the limit at about four items (Cowan, 2001). This conclusion is based on the results of experiments like one by Steven Luck and Edward Vogel (1997), which measured the capacity of STM by using a procedure called **change detection**.

METHOD Change Detection

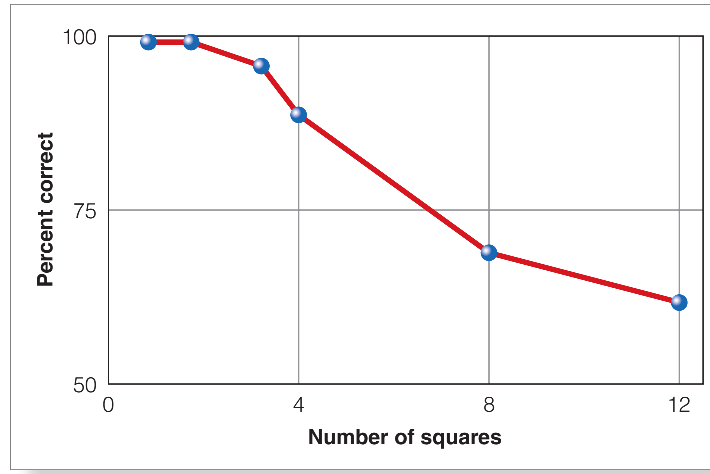
Following the "Change Detection" demonstration on page 117, we described experiments in which two pictures of a scene were flashed one after the other and the participants' task was to determine what had changed between the first and second pictures. The conclusion from these experiments was that people often miss changes in a scene.

Change detection has also been used with simpler stimuli to determine how much information a person can retain from a briefly flashed stimulus. An example of change detection is shown in **Figure 5.7**, which shows stimuli like the ones used in Luck and Vogel's experiment. The display on the left was flashed for 100 ms, followed by 900 ms of darkness and then the new display on the right. The participant's task was to indicate whether the second display was the same as or different from the first. (Notice that the color of one of the squares is changed in the second display.) This task is easy if the number of items is within the capacity of STM (**Figure 5.7a**) but becomes harder when the number of items becomes greater than the capacity of STM (**Figure 5.7b**).



➤ **Figure 5.7** (a) Stimuli used by Luck and Vogel (1997). The participant sees the first display and then indicates whether the second display is the same or different. In this example, the color of one square is changed in the second display. (b) Luck and Vogel stimuli showing a larger number of items.

(Source: Adapted from E. K. Vogel, A. W. McCollough, & M. G. Machizawa, Neural measures reveal individual differences in controlling access to working memory, *Nature*, 438, 500–503, 2005.)



➤ **Figure 5.8** Result of Luck and Vogel's (1997) experiment, showing that performance began to decrease once there were four squares in the display.

(Source: Adapted from E. K. Vogel, A. W. McCollough, & M. G. Machizawa, Neural measures reveal individual differences in controlling access to working memory, *Nature*, 438, 500–503, 2005.)

The result of Luck and Vogel's experiment, shown in **Figure 5.8,** indicates that performance was almost perfect when there were one to three squares in the arrays, but that performance began decreasing when there were four or more squares. Luck and Vogel concluded from this result that participants were able to retain about four items in their short-term memory. Other experiments, using verbal materials, have come to the same conclusion (Cowan, 2001).

These estimates of either four or five times to nine items set rather low limits on the capacity of STM. If our ability to hold items in memory is so limited, how is it possible to hold many more items in memory in some situations, as when words are arranged in a sentence? The answer to this question was proposed by George Miller, who introduced the idea of *chunking* in his "Seven, Plus or Minus Two" paper.

Chunking Miller (1956) introduced the concept of **chunking** to describe the fact that small units (like words) can be combined into larger meaningful units, like phrases, or even larger units, like sentences, paragraphs, or stories. Consider, for example, trying to remember the following words: *monkey, child, wildly, zoo, jumped, city, ringtail, young*. How many units are there in this list? There are eight words, but if we group them differently, they can form the following four pairs: *ringtail monkey, jumped wildly, young child, city zoo*. We can take this one step further by arranging these groups of words into one sentence: The *ringtail monkey jumped wildly* for the *young child* at the *city zoo.*

A **chunk** has been defined as a collection of elements that are strongly associated with one another but are weakly associated with elements in other chunks (Cowan, 2001; Gobet et al., 2001). In our example, the word *ringtail* is strongly associated with the word *monkey* but is not as strongly associated with the other words, such as *child* or *city*.

Thus, chunking in terms of meaning increases our ability to hold information in STM. We can recall a sequence of 5 to 8 unrelated words, but arranging the words to form a meaningful sentence so that the words become more strongly associated with one another increases the memory span to 20 words or more (Butterworth et al., 1990). Chunking of a series of letters is illustrated by the following demonstration.

DEMONSTRATION Remembering Letters

Read the string of letters below at a rate of about one letter every second; then cover the letters and write down as many as you can, in the correct order.

B C I F C N C A S I B B

How did you do? This task isn't easy, because it involves remembering a series of 12 individual letters, which is larger than the usual letter span of 5 to 9.

Now try remembering the following sequence of letters in order:

C I A F B I N B C C B S

How did your performance on this list compare to the one above?

Although the second list has the same letters as the first group, it was easier to remember if you realized that this sequence consists of the names of four familiar organizations. You can therefore create four chunks, each of which is meaningful, and therefore easy to remember.

K. Anders Ericsson and coworkers (1980) demonstrated an effect of chunking by showing how a college student with average memory ability was able to achieve amazing feats of memory. Their participant, S.F., was asked to repeat strings of random digits that were read to him. Although S.F. had a typical memory span of 7 digits, after extensive training (230 one-hour sessions), he was able to repeat sequences of up to 79 digits without error. How did he do it? S.F. used chunking to recode the digits into larger units that formed meaningful sequences. S.F. was a runner, so some of the sequences were running times. For example, 3,492 became "3 minutes and 49 point 2 seconds, near world-record mile time." He also used other ways to create meaning, so 893 became "89 point 3, very old man." This example illustrates an interaction between STM and LTM, because S.F created some of his chunks based on his knowledge of running times that were stored in LTM.

Chunking enables the limited-capacity STM system to deal with the large amount of information involved in many of the tasks we perform every day, such as chunking letters into words as you read this, remembering the first three numbers of familiar telephone exchanges as a unit, and transforming long conversations into smaller units of meaning.

How Much *Information* Can Be Held in Short-Term Memory?

The idea that the capacity of short-term memory can be specified as a number of items, as described in the previous section, has generated a great deal of research. But some researchers have suggested that rather than describing memory capacity in terms of "number of items," it should be described in terms of "amount of information." When referring to visual objects, information has been defined as visual features or details of the object that are stored in memory (Alvarez & Cavanagh, 2004).

We can understand the reasoning behind the idea that information is important by considering storing pictures on a computer flash drive. The number of pictures that can be stored depends on the size of the drive *and* on the size of the pictures. Fewer large pictures, which have files that contain more detail, can be stored because they take up more space in memory.

With this idea in mind, George Alvarez and Patrick Cavanagh (2004) did an experiment using Luck and Vogel's change detection procedure. But in addition to colored squares, they also used more complex objects like the ones in **Figure 5.9a**. For example, for the shaded cubes, which were the most complex stimuli, a participant would see a display containing a number of different cubes, followed by a blank interval, followed by a display

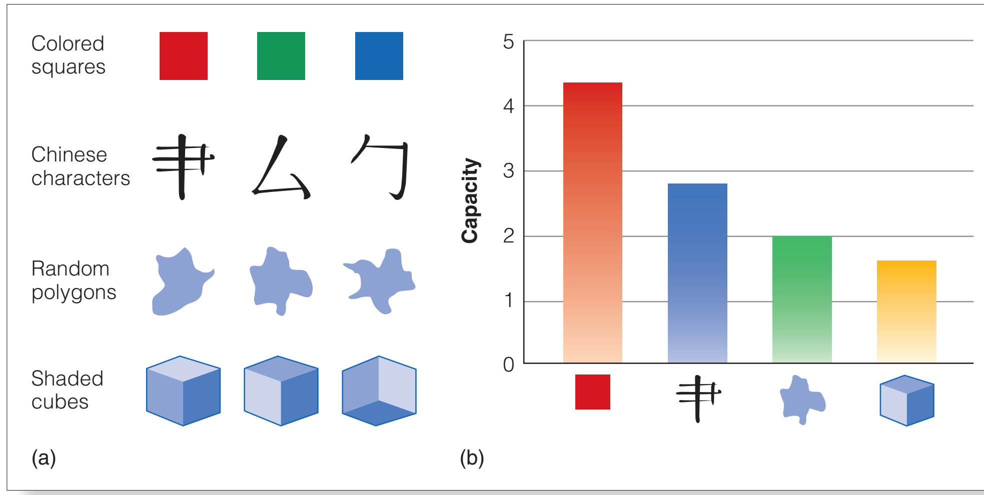


Figure 5.9 (a) Some of the stimuli used in Alvarez and Cavanagh's (2004) change detection experiment. The stimuli range from low information (colored squares) to high information (cubes). In the actual experiments, there were six different objects in each set. (b) Results showing the average number of objects that could be remembered for each type of stimulus.

(Source: Adapted from G. A. Alvarez & P. Cavanagh, The capacity of visual short-term memory is set both by visual information load and by number of objects, *Psychological Science*, 15, 106–111, 2004.)

that was either the same as the first one or in which one of the cubes was different. The participant's task was to indicate whether the two displays were the same or different.

The result, shown in **Figure 5.9b**, was that participants' ability to make the same/different judgment depended on the complexity of the stimuli. Memory capacity for the colored squares was 4.4, but capacity for the cubes was only 1.6. Based on this result, Alvarez and Cavanagh concluded that the greater the amount of information in an image, the fewer items that can be held in visual short-term memory.

Should short-term memory capacity be measured in terms of "number of items" (Awh et al., 2007; Fukuda et al., 2010; Luck & Vogel, 1997) or "amount of detailed information" (Alvaraz & Cavanagh, 2004; Bays & Husain, 2008; Brady et al., 2011)? There are experiments that argue for both ideas, and the discussion among researchers is continuing. There is, however, agreement that whether considering items or information, there are limits on how much information we can store in short-term memory.

Our discussion of STM up to this point has focused on two properties: how *long* information is held in STM and how *much* information can be held in STM. Considering STM in this way, we could compare it to a container like a leaky bucket that can hold a certain amount of water for a limited amount of time. But as research on STM progressed, it became apparent that the concept of STM as presented in the modal model was too narrow to explain many research findings. The problem was that STM was described mainly as a short-term storage mechanism. As we will see next, more goes on in short-term memory than storage. Information doesn't just sit in STM; it can be manipulated in the service of mental processes such as computation, learning, and reasoning.

TEST YOURSELF 5.1

1. The chapter began with Christine's descriptions of five different types of memory. What are these? Which are of short duration? Of long duration? Why is short-term memory important?
2. Describe Atkinson and Shiffrin's modal model of memory both in terms of its structure (the boxes connected by arrows) and the control processes. Then describe how each part of the model comes into play when you decide you want to order pizza but can't remember the pizzeria's phone number.
3. Describe sensory memory and Sperling's experiment in which he briefly flashed an array of letters to measure the capacity and duration of sensory memory.

4. How did Peterson and Peterson measure the duration of STM? What is the approximate duration of STM?
5. What is the digit span? What does this indicate about the capacity of STM?
6. Describe Luck and Vogel's change detection experiment. What is the capacity of STM according to the results of this experiment?
7. What is chunking? What does it explain?
8. What two proposals have been made about how the capacity of short-term memory should be measured? Describe Alvarez and Cavanagh's experiment and their conclusion.

Working Memory: Manipulating Information

Working memory, which was introduced in a paper by Baddeley and Hitch (1974), is defined as "a limited-capacity system for temporary storage *and manipulation of information for complex tasks such as comprehension, learning, and reasoning.*" The italicized portion of this definition is what makes working memory different from the old modal model conception of short-term memory.

Short-term memory is concerned mainly with storing information for a brief period of time (for example, remembering a phone number), whereas working memory is concerned with the *manipulation of information* that occurs during complex cognition (for example, remembering numbers while reading a paragraph). We can understand the idea that working memory is involved with the manipulation of information by considering a few examples. First, let's listen in on a conversation Rachel is having with the pizza shop:

Rachel: "I'd like to order a large pizza with broccoli and mushrooms."

Reply: "I'm sorry, but we're out of mushrooms. Would you like to substitute spinach instead?

Rachel was able to understand the pizza shop's reply by holding the first sentence, "I'm sorry, but we're out of mushrooms," in her memory while listening to the second sentence, and then making the connection between the two. If she had remembered only "Would you like to substitute spinach instead?" she wouldn't know whether it was being substituted for the broccoli or for the mushrooms. In this example, Rachel's short-term memory is being used not only for storing information but also for active processes like understanding conversations.

Another example of an active process occurs when we solve even simple math problems, such as "Multiply 43 times 6 in your head." Stop for a moment and try this while being aware of what you are doing in your head.

One way to solve this problem involves the following steps:

Visualize: 43×6.

Multiply $3 \times 6 = 18$.

Hold 8 in memory, while carrying the 1 over to the 4.

Multiply $6 \times 4 = 24$.

Add the carried 1 to the 24.

Place the result, 25, next to the 8.

The answer is 258.

It is easy to see that this calculation involves both storage (holding the 8 in memory, remembering the 6 and 4 for the next multiplication step) and active processes (carrying the 1, multiplying 6 × 4) at the same time. If only storage were involved, the problem could not be solved. There are other ways to carry out this calculation, but whatever method you choose involves both *holding* information in memory and *processing* information.

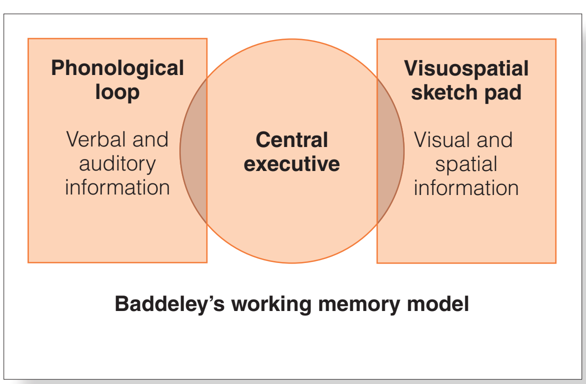
The fact that STM and the modal model do not consider dynamic processes that unfold over time is what led Baddeley and Hitch to propose that the name *working memory*, rather than *short-term memory*, be used for the short-term memory process. Current researchers often use both terms, short-term memory and working memory, when referring to the short-duration memory process, but the understanding is that the function of this process, whatever it is called, extends beyond just storage.

Returning to Baddeley, one of the things he noticed was that under certain conditions it is possible to carry out two tasks simultaneously, as illustrated in the following demonstration.

DEMONSTRATION Reading Text and Remembering Numbers

Here are four numbers: 7, 1, 4, and 9. Remember them, then cover them and read the following passage while keeping the numbers in your mind.

> Baddeley reasoned that if STM had a limited storage capacity of about the length of a telephone number, filling up the storage capacity should make it difficult to do other tasks that depend on STM. But he found that participants could hold a short string of numbers in their memory while carrying out another task, such as reading or even solving a simple word problem. How are you doing with this task? What are the numbers? What is the gist of what you have just read?



➤ **Figure 5.10** Diagram of the three main components of Baddeley and Hitch's (1974; Baddeley, 2000) model of working memory: the phonological loop, the visuospatial sketch pad, and the central executive.

According to Atkinson and Shiffrin's modal model, it should only be possible to perform one of these tasks, which should occupy the entire STM. But when Baddeley did experiments involving tasks similar to those in the previous demonstration, he found that participants were able to read while simultaneously remembering numbers.

What kind of model can take into account both (1) the dynamic processes involved in cognitions such as understanding language and doing math problems and (2) the fact that people can carry out two tasks simultaneously? Baddeley concluded that working memory must be dynamic and must also consist of a number of components that can function separately. He proposed three components: the *phonological loop*, the *visuospatial sketch pad*, and the *central executive* (**Figure 5.10**).

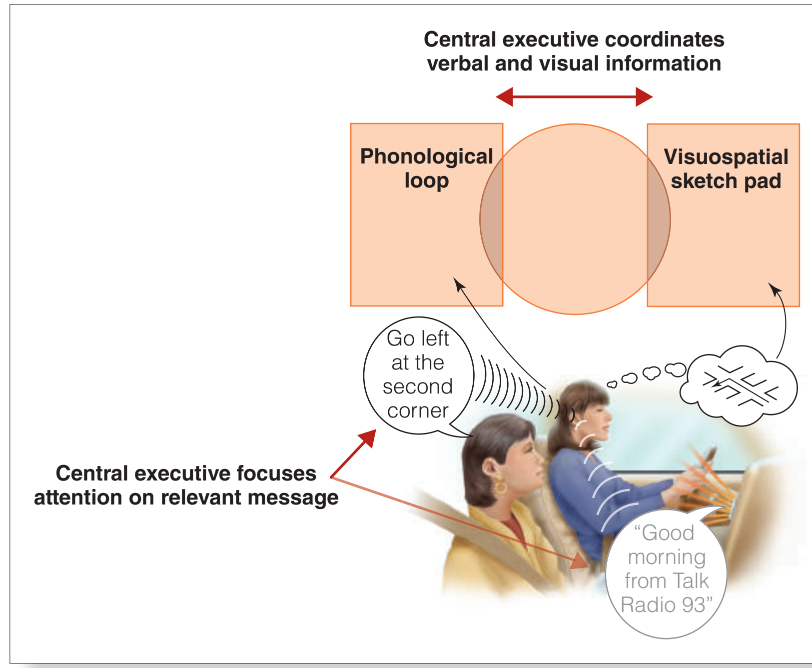
The **phonological loop** consists of two components: the **phonological store**, which has a limited capacity and holds information for only a few seconds, and the **articulatory rehearsal process**, which is responsible for rehearsal that can keep items in the phonological store from decaying. The phonological loop holds verbal and auditory information. Thus, when you are trying to remember a telephone number or a person's name, or to understand what your cognitive psychology professor is talking about, you are using your phonological loop.

The **visuospatial sketch pad** holds visual and spatial information. When you form a picture in your mind or do tasks like solving a puzzle or finding your way around campus, you are using your visuospatial sketch pad. As you can see from the diagram, the phonological loop and the visuospatial sketch pad are attached to the central executive.

The **central executive** is where the major work of working memory occurs. The central executive pulls information from long-term memory and coordinates the activity of the phonological loop and visuospatial sketch pad by focusing on specific parts of a task and deciding how to divide attention between different tasks. The central executive is therefore the "traffic cop" of the working memory system.

To understand this "traffic cop" function, imagine you are driving in a strange city, a friend in the passenger seat is reading you directions to a restaurant, and the car radio is broadcasting the news. Your phonological loop is taking in the verbal directions; your sketch pad is helping you visualize a map of the streets leading to the restaurant; and your central executive is coordinating and combining these two kinds of information (**Figure 5.11**). In addition, the central executive might be helping you ignore the messages from the radio so you can focus your attention on the directions.

We will now describe a number of phenomena that illustrate how the phonological loop handles language, how the visuospatial sketch pad holds visual and spatial information, and how the central executive uses attention to coordinate between the two.



➤ **Figure 5.11** Tasks processed by the phonological loop (hearing directions, listening to the radio) and the visuospatial sketch pad (visualizing the route) are being coordinated by the central executive. The central executive also helps the driver ignore the messages from the radio so attention can be focused on hearing the directions.

The Phonological Loop

We will describe three phenomena that support the idea of a system specialized for language: the phonological similarity effect, the word length effect, and articulatory suppression.

Phonological Similarity Effect

The **phonological similarity effect** is the confusion of letters or words that sound similar. In an early demonstration of this effect, R. Conrad (1964) flashed a series of target letters on a screen and instructed his participants to write down the letters in the order they were presented. He found that when participants made errors, they were most likely to misidentify the target letter as another letter that *sounded like* the target. For example, "F" was most often misidentified as "S" or "X," two letters that sound similar to "F," but was not as likely to be confused with letters like "E," that *looked like* the target. Thus, even though the participants *saw* the letters, the mistakes they made were based on the letters' *sounds*.

This result fits with our common experience with telephone numbers. Even though our contact with them is often visual, we usually remember them by repeating their sound over and over rather than by visualizing what the numbers looked like on the computer screen (also see Wickelgren, 1965). In present-day terminology, Conrad's result would be described as a demonstration of the phonological similarity effect, which occurs when words are processed in the phonological store part of the phonological loop.

Word Length Effect

The **word length effect** occurs when memory for lists of words is better for short words than for long words. Thus, the word length effect predicts that more words will be recalled from List 1 (below) than from List 2.

List 1: beast, bronze, wife, golf, inn, limp, dirt, star

List 2: alcohol, property, amplifier, officer, gallery, mosquito, orchestra, bricklayer

Each list contains eight words, but according to the word length effect, the second list will be more difficult to remember because it takes more time to pronounce and rehearse longer words and to produce them during recall (Baddeley et al., 1984). (Note, however, that some researchers have proposed that the word length effect does not occur under some conditions; Jalbert et al., 2011; Lovatt et al., 2000, 2002.)

In another study of memory for verbal material, Baddeley and coworkers (1975) found that people are able to remember the number of items that they can pronounce in about 1.5–2.0 seconds (also see Schweickert & Boruff, 1986). Try counting out loud, as fast as you can, for 2 seconds. According to Baddeley, the number of words you can say should be close to your digit span.

Articulatory Suppression Another way that the operation of the phonological loop has been studied is by determining what happens when its operation is disrupted. This occurs when a person is prevented from rehearsing items to be remembered by repeating an irrelevant sound, such as "the, the, the . . ." (Baddeley, 2000; Baddeley et al., 1984; Murray, 1968).

This repetition of an irrelevant sound results in a phenomenon called **articulatory suppression**, which reduces memory because speaking interferes with rehearsal. The following demonstration, which is based on an experiment by Baddeley and coworkers (1984), illustrates this effect of articulatory suppression.

DEMONSTRATION Articulatory Suppression

Task 1: Read the following list. Then turn away and recall as many words as you can.

dishwasher, hummingbird, engineering, hospital, homelessness, reasoning

Task 2: Read the following list while repeating "the, the, the . . ." out loud. Then turn away and recall as many words as you can.

automobile, apartment, basketball, mathematics, gymnasium, Catholicism

Articulatory suppression makes it more difficult to remember the second list because repeating "the, the, the . . ." overloads the phonological loop, which is responsible for holding verbal and auditory information.

Baddeley and coworkers (1984) found that repeating "the, the, the . . ." not only reduces the ability to remember a list of words, it also eliminates the word length effect (**Figure 5.12a**). According to the word length effect, a list of one-syllable words should be easier to recall than a list of longer words because the shorter words leave more space in the phonological loop for rehearsal. However, eliminating rehearsal by saying "the, the, the . . ." removes this advantage for short words, so both short and long words are lost from the phonological store (**Figure 5.12b**).

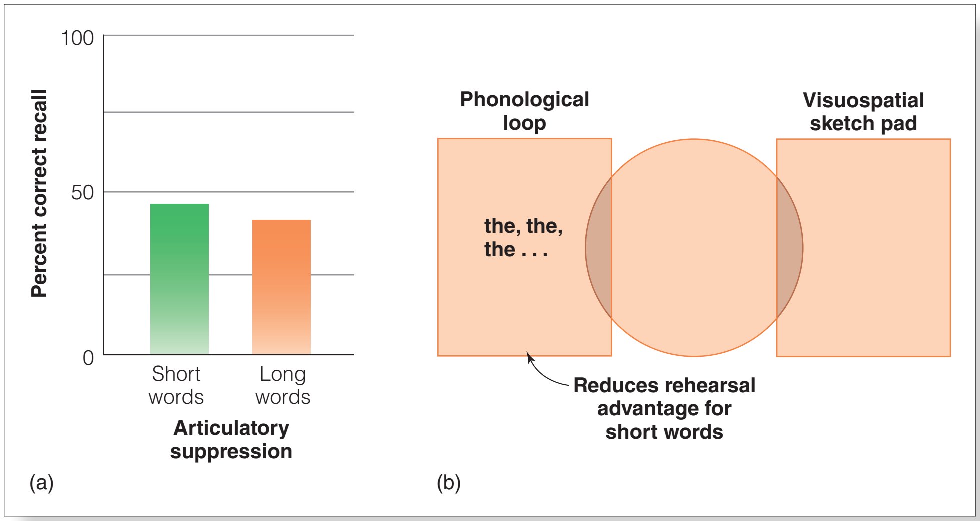
The Visuospatial Sketch Pad

The visuospatial sketch pad handles visual and spatial information and is therefore involved in the process of **visual imagery**—the creation of visual images in the mind in the absence of a physical visual stimulus. The following demonstration illustrates an early visual imagery experiment by Roger Shepard and Jacqueline Metzler (1971).

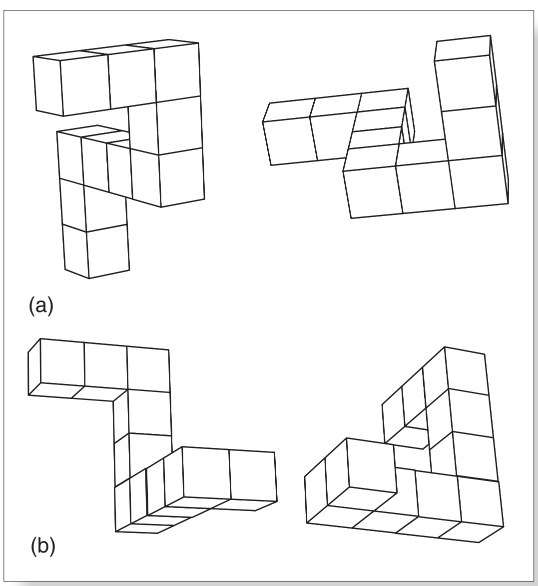
DEMONSTRATION Comparing Objects

Look at the two pictures in **Figure 5.13a** and decide, as quickly as possible, whether they represent two different views of the same object ("same") or two different objects ("different"). Also make the same judgment for the two objects in **Figure 5.13b**.

When Shepard and Metzler measured participants' reaction time to decide whether pairs of objects were the same or different, they obtained the relationship shown in **Figure 5.14** for objects that were the same. From this function, we can see that when one shape was rotated 40 degrees compared to the other shape (as in Figure 5.13a), it took 2 seconds to decide that a pair was the same shape. However, for a greater difference caused by a rotation of

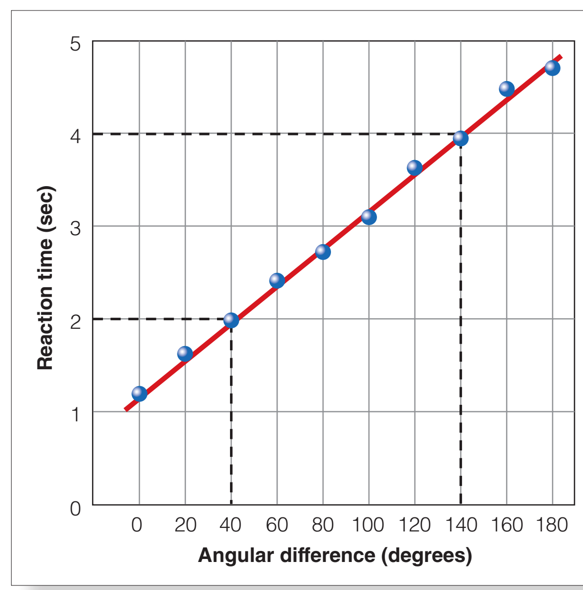


➤ **Figure 5.12** (a) Saying "the, the, the . . ." abolishes the word length effect, so there is little difference in performance for short words and long words (Baddeley et al., 1984). (b) Saying "the, the, the . . ." causes this effect by reducing rehearsal in the phonological loop.



➤ **Figure 5.13** Stimuli for the "Comparing Objects" demonstration. See text for details.

(Source: Based on R. N. Shepard & J. Metzler, Mental rotation of three-dimensional objects, *Science*, 171, Figures 1a & b, 701–703, 1971.)

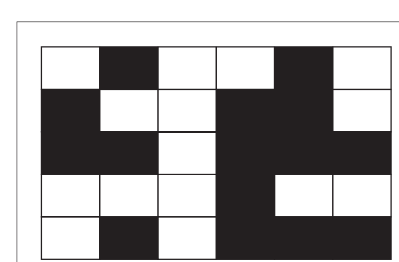


➤ **Figure 5.14** Results of Shepard and Metzler's (1971) mental rotation experiment.

(Source: Based on R. N. Shepard & J. Metzler, Mental rotation of three-dimensional objects, *Science*, 171, Figures 1a & b, 701–703, 1971.)

140 degrees (as in Figure 5.13b), it took 4 seconds. Based on this finding that reaction times were longer for greater differences in orientation, Shepard and Metzler inferred that participants were solving the problem by rotating an image of one of the objects in their mind, a phenomenon called **mental rotation**. This mental rotation is an example of the operation of the visuospatial sketch pad because it involves visual rotation through space.

Another demonstration of the use of visual representation is an experiment by Sergio Della Sala and coworkers (1999) in which participants were presented with a task like the one in the following demonstration.



➤ **Figure 5.15** Test pattern for visual recall test. After looking at this for 3 seconds, turn the page.

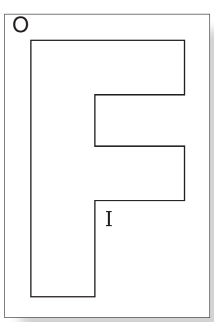
DEMONSTRATION Recalling Visual Patterns

Look at the pattern in **Figure 5.15** for 3 seconds. Then turn the page and indicate which of the squares in **Figure 5.17** need to be filled in to duplicate this pattern.

In this demonstration, the patterns are difficult to code verbally, so completing the pattern depends on visual memory. Della Sala presented his participants with patterns ranging from small (a 2 × 2 matrix with 2 shaded squares) to large (a 5 × 6 matrix with 15 shaded squares), with half of the squares being shaded in each pattern. He found that participants were able to complete patterns consisting of an average of 9 shaded squares before making mistakes.

The fact that it is possible to remember the patterns in Della Sala's matrix illustrates the operation of visual imagery. But how could the participants remember patterns consisting of an average of 9 squares? This number is at the high end of Miller's range of 5 to 9 and is far above the lower estimate of four items for STM from Luck and Vogel's experiment (Figure 5.8). A possible answer to this question is that individual squares can be combined into subpatterns—a form of chunking that could increase the number of squares remembered.

Just as the operation of the phonological loop is disrupted by interference (articulatory suppression, see page 146), so is the visuospatial sketch pad. Lee Brooks (1968) did some experiments in which he demonstrated how interference can affect the operation of the visuospatial sketch pad. The following demonstration is based on one of Brooks's tasks.



➤ **Figure 5.16** "F" stimulus for Holding a Spatial Stimulus in the Mind demonstration illustrating outside (O) and inside (I) corners. Read the directions in the text, then cover up the F.
(Source: From Brooks, 1968)

DEMONSTRATION Holding a Spatial Stimulus in the Mind

This demonstration involves visualizing a large "F" like the one in **Figure 5.16**, which has two types of corners, "outside corners" and "inside corners," two of which are labeled.

Task 1: Cover Figure 5.16, and while visualizing F in your mind, start at the upper-left corner (the one marked with the o), and, moving around the outline of the F in a clockwise direction in your mind (no looking at the figure!), *point to* "Out" in **Table 5.2** for an outside corner and "In" for an inside corner. Move your response down one level in Table 5.2 for each new corner.

Task 2: Visualize the F again, but this time, as you move around the outline of the F in a clockwise direction in your mind, *say* "Out" if the corner is an outside corner or "In" if it is an inside corner.

Which was easier, *pointing* to "Out" or "In" or *saying* "Out" or "In"? Most people find that the pointing task is more difficult. The reason is that holding the image of the letter and pointing are both visuospatial tasks, so the visuospatial sketch pad becomes overloaded. In contrast, saying "Out" or "In" is an articulatory task that is handled by the phonological loop, so speaking doesn't interfere with visualizing the F.

The Central Executive

The central executive is the component that makes working memory "work," because it is the control center of the working memory system. Its mission is not to store information but to coordinate how information is used by the phonological loop and visuospatial sketch pad (Baddeley, 1996).

Baddeley describes the central executive as being an *attention controller*. It determines how attention is focused on a specific task, how it is divided between two tasks, and how it is switched between tasks. The central executive is therefore related to *executive attention*, which we introduced in Chapter 4 (p. 123), and it is essential in situations such as when a person is attempting to simultaneously drive and use a cell phone. In this example, the executive would be coordinating phonological loop processes (talking on the phone, understanding the conversation) and sketch-pad processes (visualizing landmarks and the layout of the streets, navigating the car).

One of the ways the central executive has been studied is by assessing the behavior of patients with brain damage. As we will see later in the chapter, the frontal lobe plays a central role in working memory. It is not surprising, therefore, that patients with frontal lobe damage have problems controlling their attention. A typical behavior of patients with frontal lobe damage is **perseveration**—repeatedly performing the same action or thought even if it is not achieving the desired goal.

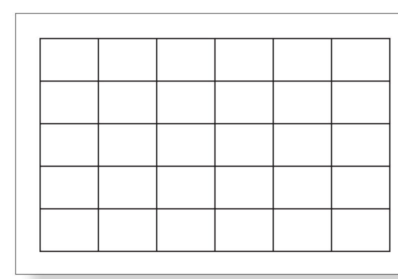
Consider, for example, a problem that can be easily solved by following a particular rule ("Pick the red object"). A person with frontal lobe damage might be responding correctly on each trial, as long as the rule stays the same. However, when the rule is switched ("Now pick the blue object"), the person continues following the old rule, even when given feedback that his or her responding is now incorrect. This perseveration represents a breakdown in the central executive's ability to control attention.

TABLE 5.2
Use for Demonstration

Corner	Point	
1	OUT	IN
2	OUT	IN
3	OUT	IN
4	OUT	IN
5	OUT	IN
6	OUT	IN
7	OUT	IN
8	OUT	IN
9	OUT	IN
10	OUT	IN

An Added Component: The Episodic Buffer

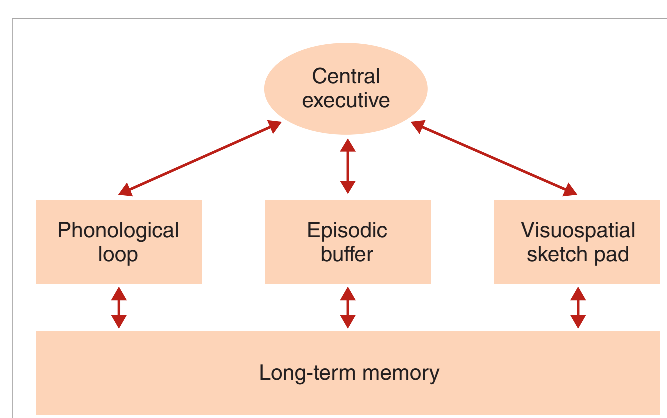
We have seen that Baddeley's three-component model can explain results such as the phonological similarity effect, the word length effect, articulatory suppression, mental rotation, and how interference affects operation of the visuospatial sketch pad. However, research has shown that there are some things the model can't explain. One of those things is that working memory can hold more than would be expected based on just the phonological loop or visuospatial sketch pad. For example, people can remember long sentences consisting of as many as 15 to 20 words. The ability to do this is related to chunking, in which meaningful units are grouped together (page 140), and it is also related to long-term memory, which is involved in knowing the meanings of words in the sentence and in relating parts of the sentence to each other based on the rules of grammar.



➤ **Figure 5.17** Answer matrix for the visual recall test. Put a check in each square that was darkened in the pattern you just looked at.

These ideas are nothing new. It has long been known that the capacity of working memory can be increased by chunking and that there is an interchange of information between working memory and long-term memory. But Baddeley decided it was necessary to propose an additional component of working memory to address these abilities. This new component, which he called the **episodic buffer**, is shown in Baddeley's new model of working memory in **Figure 5.18**. The episodic buffer can store information (thereby providing extra capacity) and is connected to LTM (thereby making interchange between working memory and LTM possible). Notice that this model also shows that the visuospatial sketch pad and phonological loop are linked to long-term memory.

The proposal of the episodic buffer represents another step in the evolution of Baddeley's model, which has been stimulating research on working memory for more than 40 years since it was first proposed. If the exact functioning of the episodic buffer seems a little vague, it is because it is a "work in progress." Even Baddeley (Baddeley et al., 2009) states that "the concept of an episodic buffer is still at a very early stage of development" (p. 57). The main



➤ **Figure 5.18** Baddeley's revised working memory model, which contains the original three components plus the episodic buffer.

"take-home message" about the episodic buffer is that it represents a way of increasing storage capacity and communicating with LTM.

Working Memory and the Brain

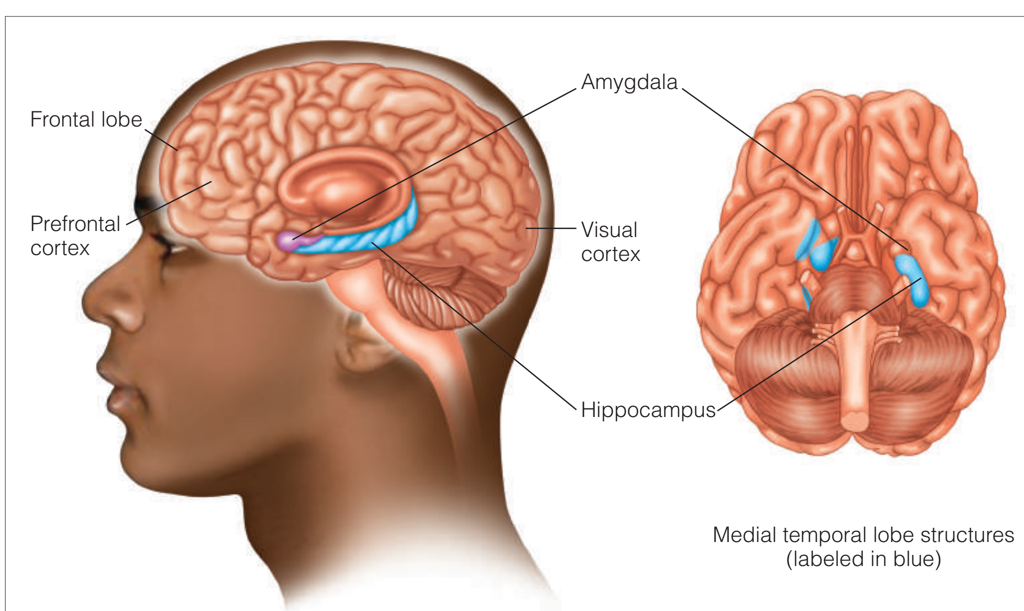
The history of research on working memory and the brain has been dominated by one structure: the prefrontal cortex (PFC) (see **Figure 5.19**). We will first describe this link between working memory and the PFC and will then consider research that has expanded the "brain map" of working memory to include many additional areas.

The Effect of Damage to the Prefrontal Cortex

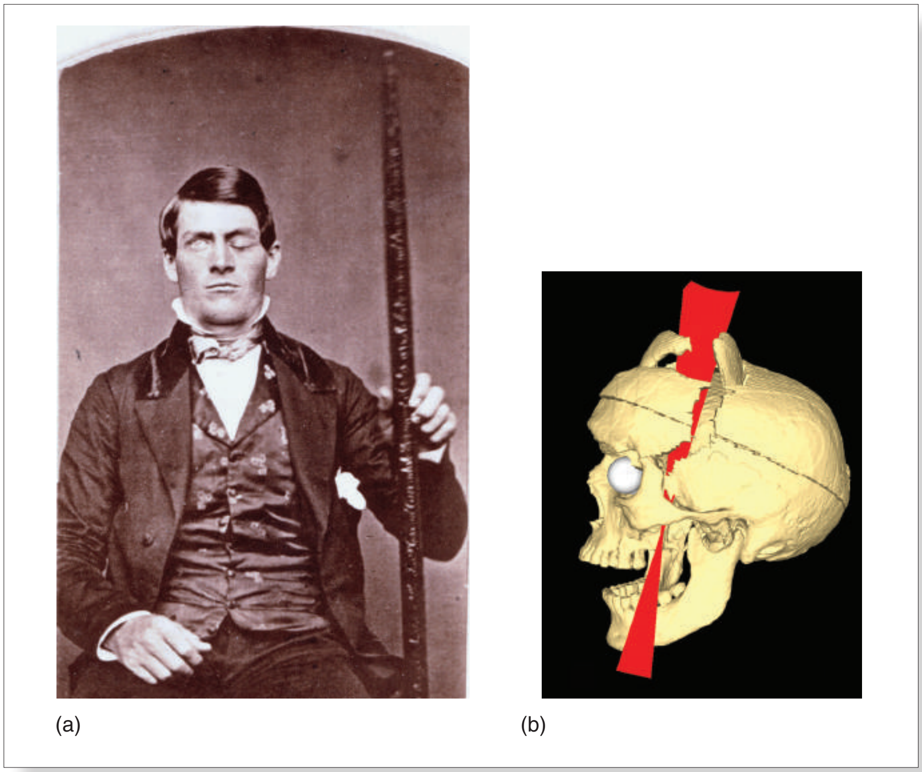
The classic example of PFC damage causing changes in behavior is the case of Phineas Gage and the tamping rod (**Figure 5.20a**). The scene takes place on a railroad track in Vermont on September 13, 1848, in which Gage was directing a work crew that was blasting rock from a railway construction project. Unfortunately for Gage, he made a fateful mistake when he jammed a 3-foot 7-inch long, 1.25-inch-wide iron tamping rod into a hole containing gunpowder, and an accidental spark ignited the gunpowder and propelled the tamping rod into this left cheek and out through the top of his head (**Figure 5.20b**), causing damage to his frontal lobe (Ratiu et al., 2004).

Amazingly, Gage survived, but reports from the time noted that the accident had changed Gage's personality from an upstanding citizen to a person with low impulse control, poor ability to plan, and poor social skills. Apparently, there is some uncertainty as to the accuracy of these early descriptions of Gage's behavior (Macmillan, 2002). Nonetheless, reports about Gage, whether accurate or not, gave rise to the idea that the frontal lobes are involved in a variety of mental functions, including personality and planning.

Although Gage's accident and spectacular recovery brought the frontal lobes to people's attention, our present knowledge about the frontal lobe has been deduced from modern neuropsychological case studies and controlled behavioral and neurophysiological



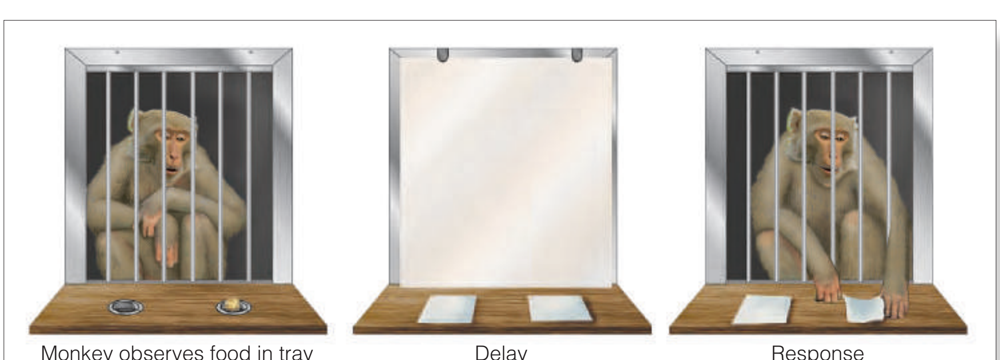
➤ **Figure 5.19** Cross section of the brain showing some key structures involved in memory. The discussion of working memory focuses on the prefrontal cortex and the visual cortex. The hippocampus, amygdala, and frontal cortex will be discussed in Chapters 6 and 7.



➤ **Figure 5.20** (a) Phineas Gage posing with the tamping rod. (b) Diagram showing how the tamping rod went through Gage's head.

experiments. We've noted that damage to the frontal lobe causes problems in controlling attention, which is an important function of the central executive.

An example of animal research that explored the effect of frontal lobe damage on memory tested monkeys using the **delayed-response task**, which required a monkey to hold information in working memory during a delay period (Goldman-Rakic, 1990, 1992). **Figure 5.21** shows the setup for this task. The monkey sees a food reward in one of two food wells. Both wells are then covered, a screen is lowered, and then there is a delay before the screen is raised again. When the screen is raised, the monkey must remember which well had the food and uncover the correct food well to obtain a reward. Monkeys can be trained to accomplish this task. However, if their PFC is removed, their performance drops to chance level, so they pick the correct food well only about half of the time.



➤ **Figure 5.21** The delayed-response task being administered to a monkey.

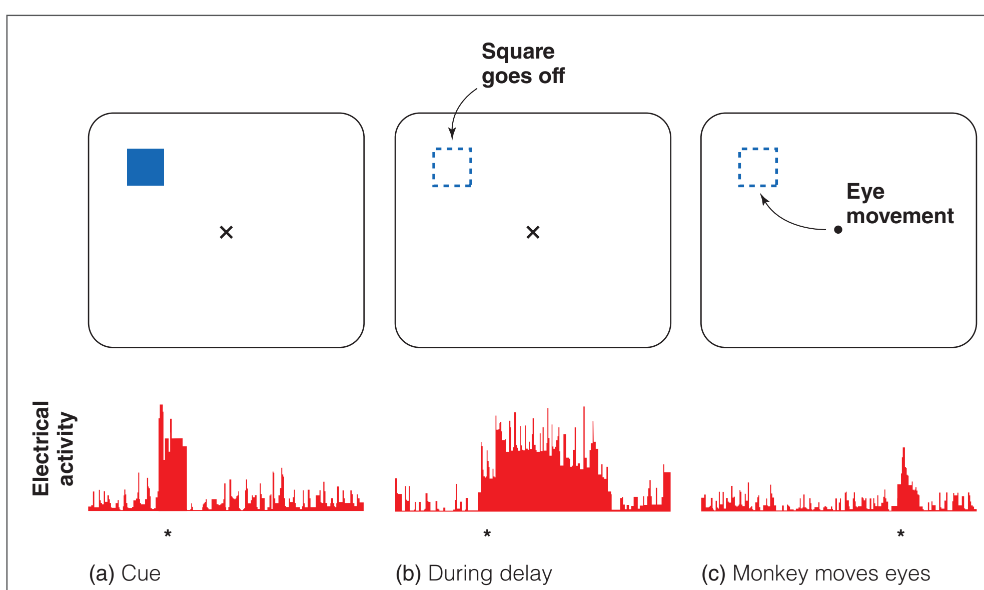
This result supports the idea that the PFC is important for holding information for brief periods of time. In fact, it has been suggested that one reason we can describe the memory behavior of very young infants as "out of sight, out of mind" (when an object that the infant can see is then hidden from view, the infant behaves as if the object no longer exists) is that their frontal and prefrontal cortex do not become adequately developed until about 8 months of age (Goldman-Rakic, 1992).

Prefrontal Neurons That Hold Information

An important characteristic of memory is that it involves *delay* or *waiting*. Something happens, followed by a delay, which is brief for working memory; then, if memory is successful, the person remembers what has happened. Researchers, therefore, have looked for physiological mechanisms that hold information about events after they are over.

Shintaro Funahashi and coworkers (1989) conducted an experiment in which they recorded from neurons in a monkey's PFC while the monkey carried out a delayed-response task. The monkey first looked steadily at a fixation point, X, while a square was flashed at one position on the screen (**Figure 5.22a**). In this example, the square was flashed in the upper-left corner (on other trials, the square was flashed at different positions on the screen). This caused a small response in the neuron.

After the square went off, there was a delay of a few seconds. The nerve firing records in **Figure 5.22b** show that the neuron was firing during this delay. This firing is the neural record of the monkey's working memory for the position of the square. After the delay, the fixation X went off. This was a signal for the monkey to move its eyes to where the square



➤ **Figure 5.22** Results of an experiment showing the response of neurons in the monkey's prefrontal cortex during an attentional task. Neural responding is indicated by an asterisk (*). (a) A cue square is flashed at a particular position, causing the neuron to respond. (b) The square goes off, but the neuron continues to respond during the delay. (c) The fixation X goes off, and the monkey demonstrates its memory for the location of the square by moving its eyes to where the square was.

(Source: Adapted from S. Funahashi, C. J. Bruce, & P. S. Goldman-Rakic, Mnemonic coding of visual space in the primate dorsolateral prefrontal cortex, *Journal of Neurophysiology*, 6, 331–349, 1989.)

had been flashed (**Figure 5.22c**). The monkey's ability to do this provides behavioral evidence that it had, in fact, remembered the location of the square.

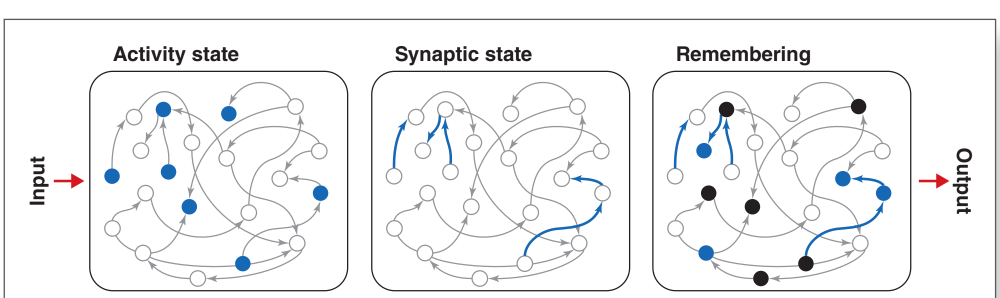
The key result of this experiment was that Funahashi found neurons that responded only when the square was flashed in a *particular location* and that these neurons *continued responding during the delay*. For example, some neurons responded only when the square was flashed in the upper-right corner and then during the delay; other neurons responded only when the square was presented at other positions on the screen and then during the delay. The firing of these neurons indicates that an object was presented at a particular place, and this information about the object's location remains available for as long as these neurons continue firing (also see Funahashi, 2006).

The Neural Dynamics of Working Memory

The idea that information can be held in working memory by neural activity that continues across a time gap, as in Figure 5.22b, fits with the idea that neural firing transmits information in the nervous system. But some researchers have proposed that information can be held during the delay by a mechanism that doesn't involve continuous firing.

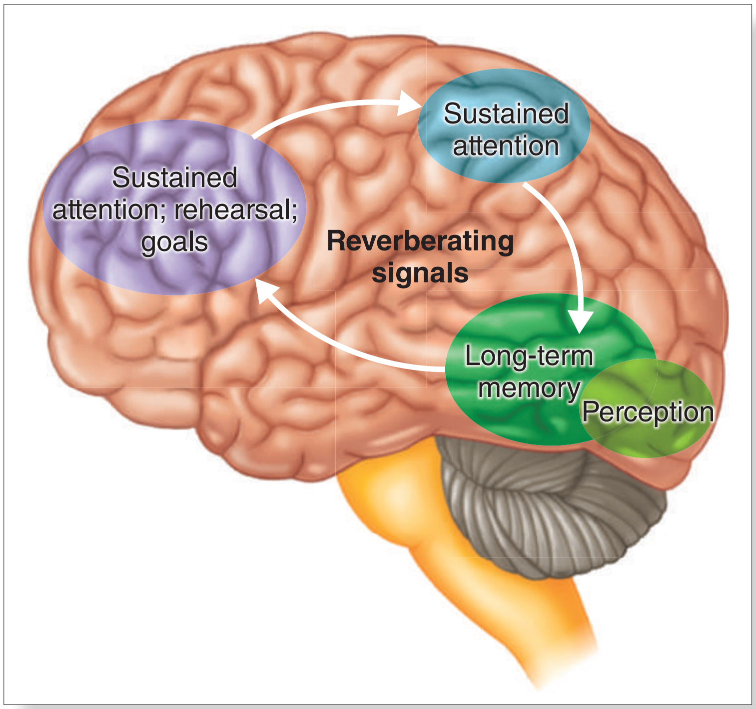
One idea, proposed by Mark Stokes (2015), is that information can be stored by short-term changes in neural networks, as shown in **Figure 5.23**. **Figure 5.23a** shows the *activity state*, in which information to be remembered causes a number of neurons, indicated by the dark circles, to briefly fire. This firing doesn't continue, but causes the *synaptic state*, shown in **Figure 5.23b**, in which a number of connections between neurons, indicated by the darker lines, are strengthened. These changes in connectivity, which Stokes calls **activity-silent working memory**, last only a few seconds, but that is long enough for working memory. Finally, when the memory is being retrieved, the memory is indicated by the pattern of firing in the network, shown by the dark circles in **Figure 5.23c**.

Thus, in Stokes's model, information is held in memory not by continuous nerve firing but by a brief change in the connectivity of neurons in a network. Other researchers have proposed other ways of holding information in working memory that don't require continuous neural firing (Lundquist et al., 2016; Murray et al., 2017). These models are based on experiments and computations too complex to describe here, and all are speculative. But the idea that information can be stored in the nervous system by changes in the



➤ **Figure 5.23** Diagram showing Stokes's (2015) proposal that information can be stored in working memory by changes in the connectivity of a neural network. (a) Activity state, showing that some neurons in the network (blue circles) are activated by the incoming stimulus. (b) Synaptic state, showing connections that have been strengthened between neurons in the network (blue lines). (c) Activity associated with the memory.

(Source: Stokes, M. G, 'Activity-silent' working memory in prefrontal cortex: a dynamic coding framework. Trends in Cognitive Sciences, 19(7), 394–405. Figure 2a, top, p. 397, 2015.)



➤ **Figure 5.24** Map showing some of the areas of the brain that are involved in working memory. This simplified version of the working memory structures proposed by Ericsson et al. (2015) indicates not only that a number of areas are associated with working memory, but that they communicate with each other.

Source: Ericsson et al., Neurocognitive architecture of working memory, *Neuron* 88, 33–46. Figure 10d, page 35, 2015.)

connections in neural networks is one of the "hot" topics of current research on the neural mechanisms of memory (Kaldy & Sigala, 2017).

Another current idea about working memory is that it involves physiological processes that extend beyond the PFC. It isn't hard to see why working memory would involve brain areas in addition to the frontal lobes. Just look back at the woman driving the car in Figure 5.11, who is using her central executive to switch her attention from one thing to another, which involves visual capacities, as she imagines the road layout, and verbal capacities, as she listens to her companion's directions. Working memory, therefore, involves an interplay between a number of areas of the brain. This interplay is symbolized by the interaction between brain areas in **Figure 5.24**, which depicts a network based on the research on a large number of experiments (Curtis & Espisoto, 2003; Ericsson et al., 2015; Lee & Baker, 2016; Riley & Constantinidis, 2016). This idea that a number of areas of the brain are involved in working memory is an example of distributed representation, which we introduced in Chapter 2 (page 43).

SOMETHING TO CONSIDER: WHY IS MORE WORKING MEMORY BETTER?

Is working memory the same in different people? The answer to this question—that there are individual differences in the capacity of people's working memory—shouldn't be surprising. After all, people differ in physical capabilities, and it is a common observation that some people have better memory than others. But researchers' interest in individual differences in working memory extends beyond simply demonstrating that differences exist to demonstrating how differences in working memory influence cognitive functioning and behavior.

Meredyth Daneman and Patricia Carpenter (1980) carried out one of the early experiments on individual differences in working memory capacity by developing a test for working memory capacity and then determining how individual differences were related to reading comprehension. The test they developed, the **reading span test**, required participants to read a series of 13- to 16-word sentences such as these:

(1) *When at last his eyes opened, there was no glimmer of strength, no shade of angle.*

(2) *The taxi turned up Michigan Avenue where they had a clear view of the lake.*

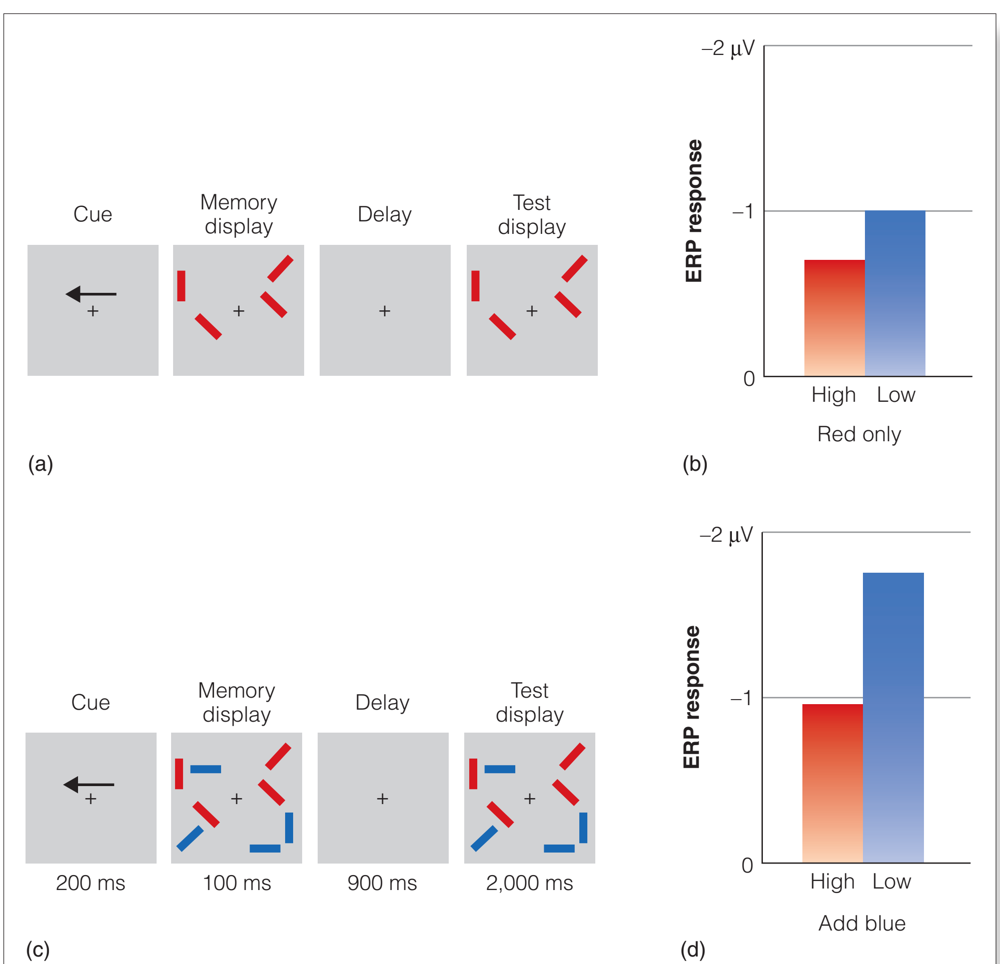
Each sentence was seen briefly as it was being read, then the next sentence was presented. Immediately after reading the last sentence, the participant was asked to remember the last word in each sentence in the order that they occurred. The participant's **reading span** was the number of sentences they could read, and then correctly remember all of the last words.

Participants' reading spans ranged from 2 to 5, and the size of the reading span was highly correlated with their performance on a number of reading comprehension tasks and their verbal SAT score. Daneman and Carpenter concluded that working memory capacity is a crucial source of individual differences in reading comprehension. Other research has shown that higher working memory capacity is related to better academic performance

(Best & Miller, 2010; Best et al., 2011), better chance of graduating from high school (Fitzpatrick et al., 2015), the ability to control emotions (Schmeichel et al., 2008), and greater creativity (De Drue et al., 2012).

But what is it about differences in working memory capacity that results in these outcomes? Edmund Vogel and coworkers (2005) focused on one component of working memory: the control of attention by the central executive. They first separated participants into two groups based on their performance on a test of working memory. Participants in the *high-capacity group* were able to hold a number of items in working memory; participants in the *low-capacity group* were able to hold fewer items in working memory.

Participants were tested using the change detection procedure (see Method: Change Detection, page 139). **Figure 5.25a** shows the sequence of stimuli: (1) they first saw a cue indicating whether to direct their attention to the red rectangles on the left side or the red rectangles on the right side of the displays that followed. (2) They then saw a memory display for one-tenth of a second followed by (3) a brief blank screen and then (4) a test display. Their task was to indicate whether the cued red rectangles in the test display had the same or different orientations than the ones in the memory display. While they were making this judgment, a brain response called the *event-related potential* was measured, which indicated how much space was used in working memory as they carried out the task.



➤ **Figure 5.25** (a) Sequence for the Vogel et al. (2005) task. The arrow in this example tells the participant to pay attention to the left side of the memory and test displays. The task is to indicate whether the red rectangles on the attended side are the same or different in the two displays. (b) ERP response for low- and high-capacity participants for the task in part (a). (c) Display with blue bars added. These bars are added to distract the participants, who are supposed to be focusing on the red rectangles. (d) ERP response for the task in part (c).

(Source: Based on E. K. Vogel, A. W. McCollough, & M. G. Machizawa, Neural measures reveal individual differences in controlling access to working memory, *Nature*, 438, 500–503, 2005.)

Thomas Barwick/Taxi/Getty Images

Our memories record many different things. This chapter distinguishes between episodic memory—memories that enable us to "relive" in our mind events that have occurred in our lives—and semantic memory—memories for facts that don't depend on remembering specific events. These women may be able to "relive," years later, the experience of taking a "selfie" as well as what the occasion was that brought them together. This is episodic memory. But even if they were to forget taking the selfie and what happened on that particular day, they would likely still remember each other, along with characteristics specific to each person. This is semantic memory. We will see that episodic memory and semantic memory compliment each other and interact to create the richness of our lives.

Long-Term Memory: Structure

6

SOME QUESTIONS WE WILL CONSIDER

- How does damage to the brain affect the ability to remember what has happened in the past and the ability to form new memories of ongoing experiences? (170)
- How are memories for personal experiences, like what you did last summer, different from memories for facts, like the capital of your state? (172)
- How do the different types of memory interact in our everyday experience? (174, 182)
- How has memory loss been depicted in popular films? (185)

Christine's memories, from Chapter 5, were varied, ranging from short-lived (a briefly flashed face, a rapidly fading phone number) to longer-lasting (a memorable picnic, the date of a person's birthday, how to ride a bike) (Figure 5.1, page 130) The theme of this chapter is "division and interaction."

Division refers to distinguishing between different types of memory. We introduced this idea in Chapter 5 when we divided Christine's memory into *short-term* and *long-term* and further divided long-term memory into *episodic memory* (memory for specific experiences from the past); *semantic memory* (memory for facts); and *procedural memory* (memory for how to carry out physical actions).

Distinguishing between different types of memory is useful because it divides memory into smaller, easier-to-study components. But this division has to be based on real differences between the components. Thus, one of our goals will be to consider evidence that these different components are based on different mechanisms. We will do this by considering the results of (1) behavioral experiments, (2) neuropsychological studies of the effects of brain damage on memory, and (3) brain imaging experiments. *Interaction* refers to the fact that the different types of memory can interact and share mechanisms. We begin by revisiting short-term memory.

Comparing Short-Term and Long-Term Memory Processes

Long-term memory (LTM) is the system that is responsible for storing information for long periods of time. One way to describe LTM is as an "archive" of information about past events in our lives and knowledge we have learned. What is particularly amazing about this storage is that it stretches from just a few moments ago to as far back as we can remember.

The long time span of LTM is illustrated in **Figure 6.1**, which shows what a student who has just taken a seat in class might be remembering about events that have occurred at various times in the past. His first recollection—that he has just sat down—would be in his

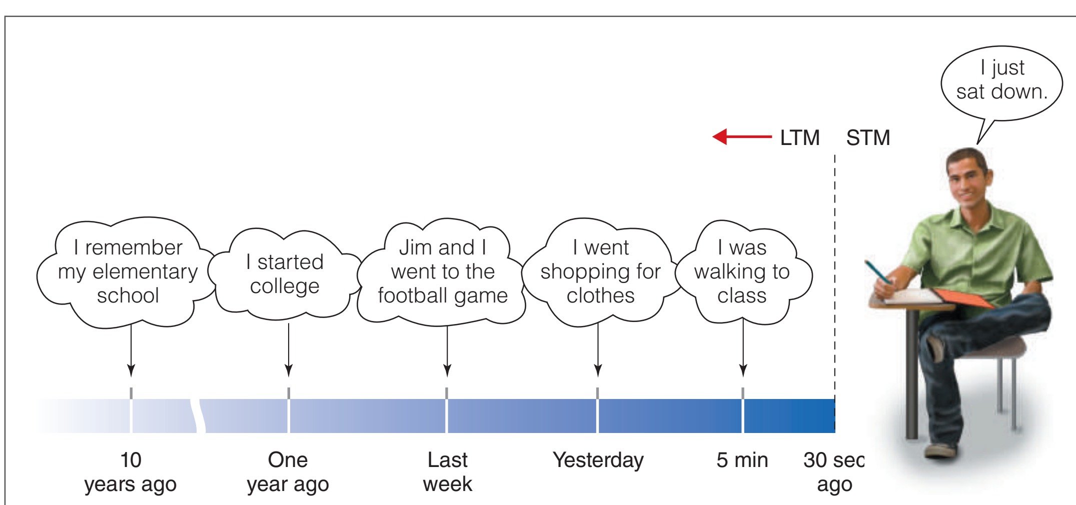


Figure 6.1 Long-term memory covers a span that stretches from about 30 seconds ago to your earliest memories. Thus, all of this student's memories, except the memory "I just sat down" and anything the student was rehearsing, would be classified as long-term memories.

short-term/working memory (STM/WM) because it happened within the last 30 seconds. But everything before that—from his recent memory that 5 minutes ago he was walking to class, to a memory from 10 years earlier of the elementary school he attended in the third grade—is part of long-term memory.

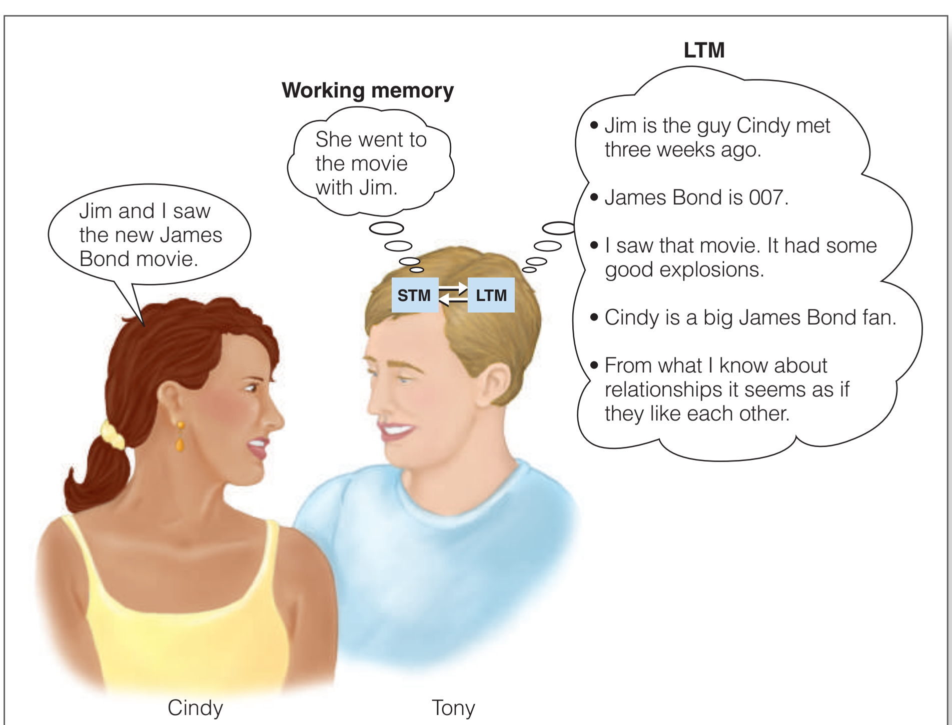
Let's begin by comparing the two types of memory on either side of the line separating short-term and long-term memory. How are these two types of memory similar, and how are they different?

Our starting point for comparing LTM and STM/WM takes us back to our discussion of STM, when we noted that one of the problems with STM is that most research emphasized its storage function—how much information it can hold and for how long. This led to the proposal of working memory, with its emphasis on dynamic processes that are needed to explain complex cognitions such as understanding language, solving problems, and making decisions.

A similar situation exists for LTM. Although retaining information about the past is an important characteristic of LTM, we also need to understand how this information is used. We can do this by focusing on the dynamic aspects of how LTM operates, including how it interacts with working memory to create our ongoing experience.

Consider, for example, what happens when Tony's friend Cindy says, "Jim and I saw the new James Bond movie last night" (**Figure 6.2**). As Tony's working memory is holding the exact wording of that statement in his mind, it is simultaneously accessing the meaning of words from LTM, which helps him understand the meaning of each of the words that make up the sentence.

Tony's LTM also contains a great deal of additional information about movies, James Bond, and Cindy. Although Tony might not consciously think about all of this information (after all, he has to pay attention to the next thing that Cindy is going to tell him), it is all



➤ **Figure 6.2** Tony's working memory, which is dealing with the present, and his LTM, which contains knowledge relevant to what is happening, work together as Cindy tells him something.

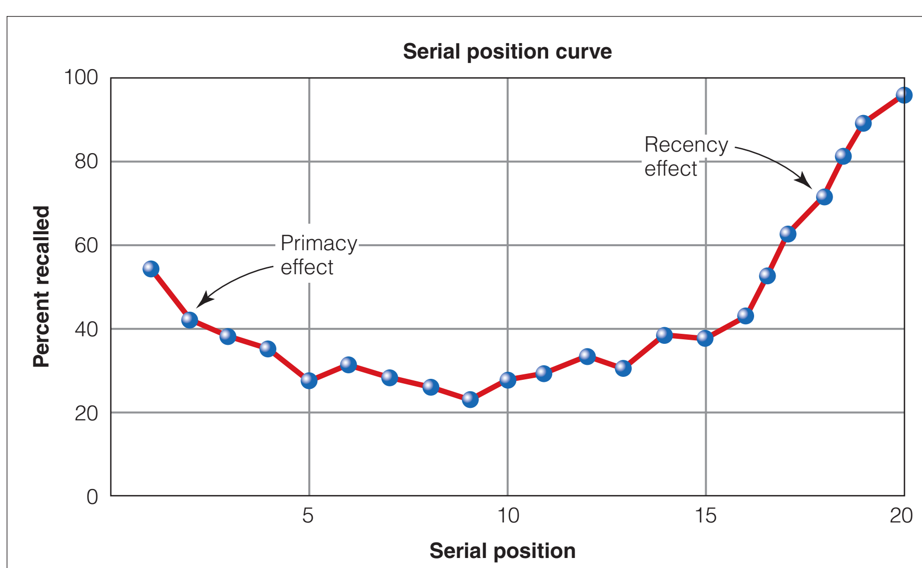
there in his LTM and adds to his understanding of what he is hearing and his interpretation of what it might mean. LTM therefore provides both an archive that we can refer to when we want to remember events from the past and a wealth of background information that we are constantly consulting as we use working memory to make contact with what is happening at a particular moment.

The interplay between what is happening in the present and information from the past, which we described in the interaction between Tony and Cindy, is based on the distinction between STM/WM and LTM. Beginning in the 1960s, a great deal of research was conducted that was designed to distinguish between short-term and long-term processes. In describing these experiments, we will identify the short-term process as short-term memory (STM) for the early experiments that used that term and as working memory (WM) for more recent experiments that focused on working memory. A classic experiment by B.B. Murdock, Jr. (1962) studied the distinction between STM and LTM by measuring a function called the *serial position curve*.

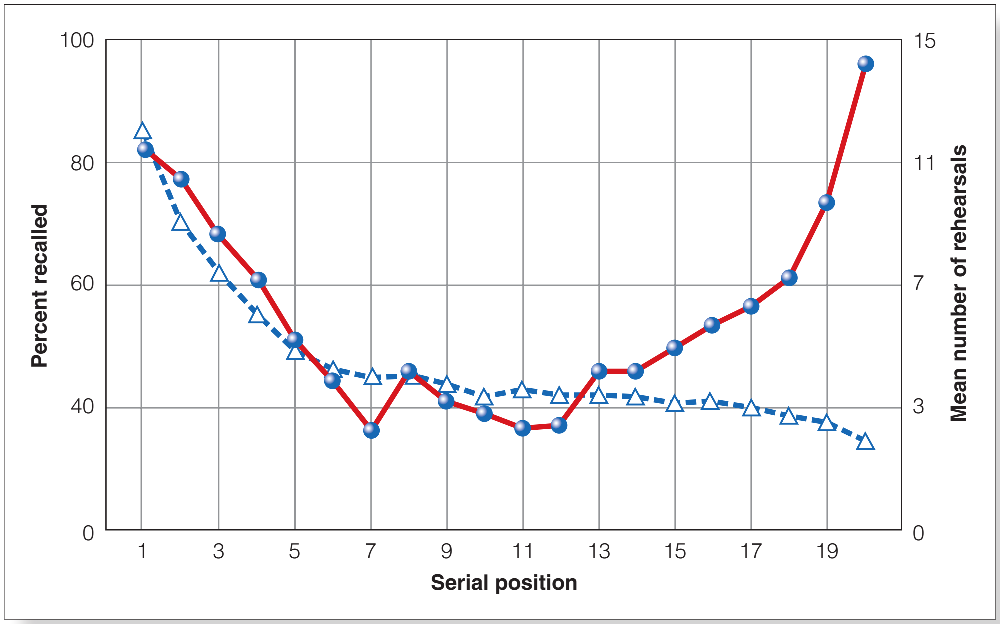
Serial Position Curve

A **serial position curve** is created by presenting a list of words to a participant, one after another. After the last word, the participant writes down all the words he or she remembers, in any order. The serial position curve in **Figure 6.3**, which plots percentage of a group of participants that recalled each word versus its position in the list, indicates that memory is better for words at the beginning of the list and at the end of the list than for words in the middle (Murdoch, 1962).

The finding that participants are more likely to remember words presented at the beginning of a sequence is called the **primacy effect**. A possible explanation of the primacy effect is that participants had time to rehearse the words at the beginning of the sequence and transfer them to LTM. According to this explanation, participants begin rehearsing the first word right after it is presented; because no other words have been presented, the first word receives 100 percent of the participant's attention. When the second word is presented, attention becomes spread over two words, and so on; as additional words are presented, less rehearsal is possible for later words.



➤ **Figure 6.3** Serial position curve (Murdoch, 1962). Notice that memory is better for words presented at the beginning of the list (primacy effect) and at the end (recency effect).
(Source: B. B. Murdock, Jr., The serial position effect in free recall, Journal of Experimental Psychology, 64, 482–488.)

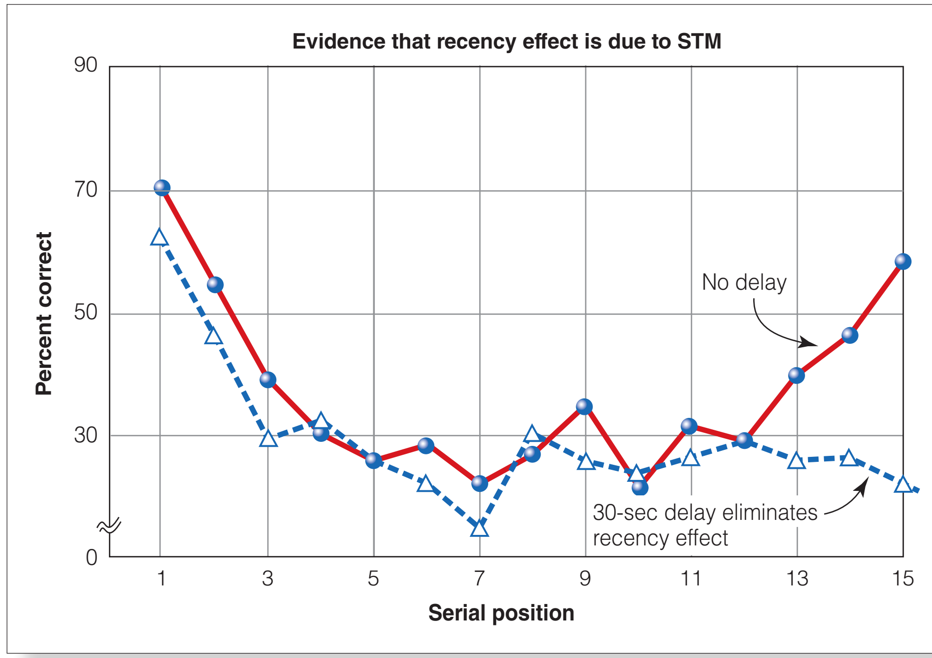


➤ **Figure 6.4** Results of Rundus's (1971) experiment. The solid red line is the usual serial position curve. The dashed blue line indicates how many times the subjects rehearsed (said out loud) each word on the list. Note how the rehearsal curve matches the initial part of the serial position curve.

(Source: D. Rundus, Analysis of rehearsal processes in free recall, Journal of Experimental Psychology, 89, 63–77, Figure 1, p. 66, 1971.)

Dewey Rundus (1971) tested this idea that the primacy effect occurs because participants have more time to rehearse words at the beginning of the list. He first presented a list of 20 words at a rate of 1 word every 5 seconds, and after the last word was presented, he asked his participants to write down all the words they could remember. The resulting serial position curve, which is the red curve in **Figure 6.4**, shows the same primacy effect as Murdoch's curve in Figure 6.3. But Rundus added a twist to his experiment by presenting another list and asking his participants to repeat the words out loud during the 5-second intervals between words. Participants were not told which words to repeat from the list—just that they should keep repeating words during the 5-second intervals between words. The dashed blue curve, which indicates how many times each word was repeated, bears a striking resemblance to the first half of the serial position curve. Words presented early in the list were rehearsed more, and were also more likely to be remembered later. This result supports the idea that the primacy effect is related to the longer rehearsal time available for words at the beginning of the list.

The better memory for the stimuli presented at the end of a sequence is called the **recency effect.** The explanation for the recency effect is that the most recently presented words are still in STM and therefore are easy for participants to remember. To test this idea, Murray Glanzer and Anita Cunitz (1966) first created a serial position curve in the usual way (red curve in **Figure 6.5**). Then, in another experiment, they had participants recall the words after they had counted backwards for 30 seconds right after hearing the last word of the list. This counting prevented rehearsal and allowed time for information to be lost from STM. The result, shown in the blue dashed curve in Figure 6.5, was what we would predict: The delay caused by the counting eliminated the recency effect. Glanzer and Cunitz therefore concluded that the recency effect is due to storage of recently presented items in STM. The serial position results in Figures 6.3, 6.4, and 6.5 are summarized in **Table 6.1**.



➤ **Figure 6.5** Results of Glanzer and Cunitz's (1966) experiment. The serial position curve has a normal recency effect when the memory test is immediate (solid red line), but no recency effect occurs if the memory test is delayed for 30 seconds (dashed blue line).

(Source: M. Glanzer & A. R. Cunitz, Two storage mechanisms in free recall, Journal of Verbal Learning and Verbal Behavior, 5, 351–360, Figures 1 & 2. Copyright © 1966 Elsevier Ltd. Republished with permission.)

TABLE 6.1
Serial Position Experiments

Figure	Procedure	Illustrates
Figure 6.3	Participant begins recall immediately after hearing the list of words.	Primacy effect and recency effect.
Figure 6.4	List is presented and participant repeats words out loud in 5-second intervals between words.	Words at the beginning of the list are repeated more, so they are more likely to get into LTM.
Figure 6.5	Participant begins recall after counting backwards for 30 seconds.	Recency effect is eliminated because rehearsal is prevented.

Coding in Short-Term and Long-Term Memory

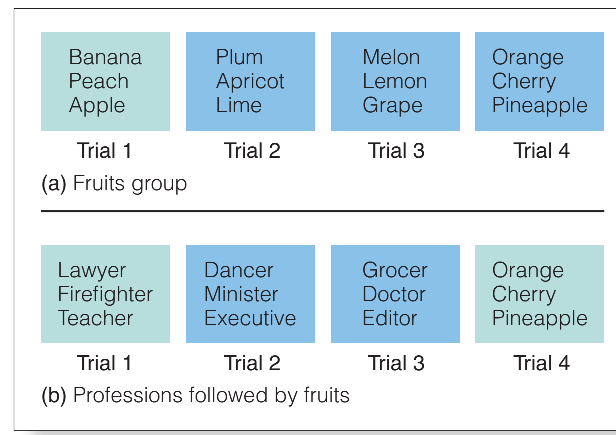
We can also distinguish between STM and LTM by comparing the way information is *coded* by the two systems. **Coding** refers to the form in which stimuli are represented. For example, as we discussed in Chapter 2, a person's face can be represented by the pattern of firing of a number of neurons (see page 37). Determining how a stimulus is represented by the firing of neurons is a *physiological approach to coding*.

In this section, we will be taking a *mental approach to coding* by asking how a stimulus or an experience is represented in the mind. To compare the way information is represented in the mind in STM and LTM systems, we describe visual coding (coding in the mind in the form of a visual image), auditory coding (coding in the mind in the form of a sound), and semantic coding (coding in the mind in terms of meaning) in both STM and LTM.

Visual Coding in Short-Term and Long-Term Memory You probably used visual coding in the demonstration "Recalling Visual Patterns" (Chapter 5, page 147), in which you were asked to remember the visual pattern in Figure 5.15. This is visual coding in STM if you remembered the pattern by representing it visually in your mind. You also use visual coding in LTM when you visualize a person or place from the past. For example, if you are remembering your fifth-grade teacher's face, you are using visual coding.

Auditory Coding in Short-Term and Long-Term Memory Auditory coding in STM is illustrated by Conrad's demonstration of the phonological similarity effect (see page 145), which showed that people often misidentify target letters as another letter that sounds like the target (confusing "F" and "S," for example, which don't look alike but which sound alike). Auditory coding occurs in LTM when you "play" a song in your head.

Semantic Coding in Short-Term Memory: The Wickens Experiment An experiment by Delos Wickens and coworkers (1976) provides an example of semantic coding in STM. **Figure 6.6** shows the experimental design. On each trial, participants were presented with words related to either (a) fruits (the "Fruits group") or (b) professions (the "Professions group"). Participants in each group listened to three words (for example, *banana, peach, apple* for the Fruits group), counted backward for 15 seconds, and then attempted to recall the three words. They did this for a total of four trials, with different words presented on each trial. Because participants recalled the words so soon after hearing them, they were using their STM.



➤ **Figure 6.6** Stimuli for the Wickens et al. (1976) experiment. (a) Subjects in the Fruits group are presented with the names of three fruits on each trial. After each presentation, subjects counted backwards for 15 seconds and then recalled the names of the fruits. (b) Subjects in the Professions group were presented with the names of three professions on trials 1, 2, and 3, and with the names of three fruits on trial 4. They also counted backwards for 15 seconds before recalling the names on each trial.

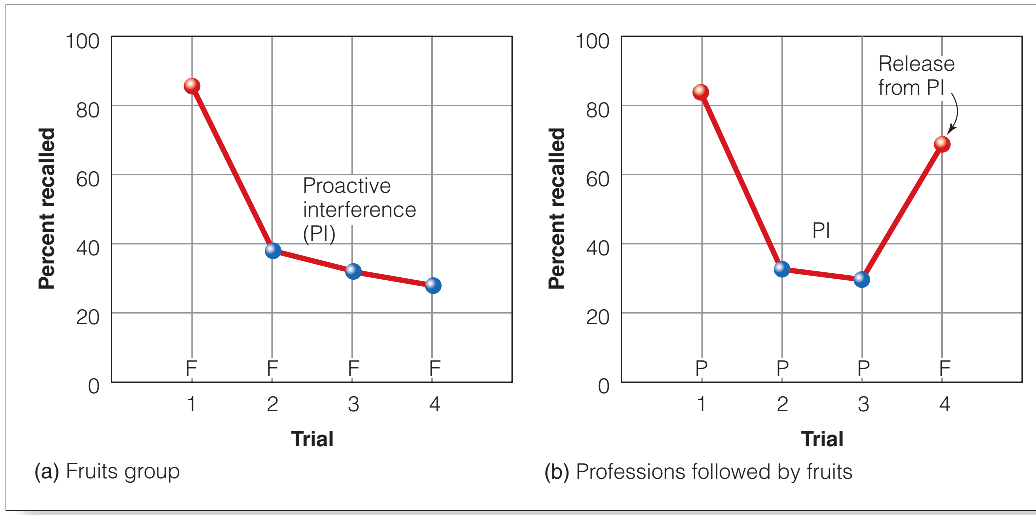
(Source: Based on D. D. Wickens, R. E. Dalezman, & F. T. Eggemeier, Multiple encoding of word Attributes in memory, Memory & Cognition, 4, 307–310, 1976.)

The basic idea behind this experiment was to create **proactive interference**—the decrease in memory that occurs when previously learned information interferes with learning new information—by presenting words from the same *category* on a series of trials. For example, for the Fruits group, *banana, peach*, and *apple* were presented in trial 1 and *plum, apricot*, and *lime* were presented in trial 2. Proactive interference is illustrated by the falloff in performance on each trial, shown by the blue data points in **Figure 6.7a**.

Evidence that this interference for the Fruits group can be attributed to the *meanings* of the words (all of the words were fruits) is provided by the results for the Professions group shown in **Figure 6.7b**. As for the Fruits group, performance is high on trial 1 and then drops on trials 2 and 3 because all of the words are names of professions. But on trial 4, the names of fruits are presented. Because these words are from a different category, the proactive interference that built up as the professions were being presented is absent, and performance increases on trial 4. This increase in performance is called **release from proactive interference**.

What does release from proactive interference tell us about coding in STM? The key to answering this question is to realize that the release from proactive interference that occurs in the Wickens experiment depends on the words' *categories* (fruits and professions). Because placing words into categories involves the *meanings* of the words, and because participants were recalling the words 15 seconds after they heard them, this represents an effect of semantic coding in STM.

Semantic Coding in Long-Term Memory: The Sachs Experiment A study by Jacqueline Sachs (1967) demonstrated semantic coding in LTM. Sachs had participants listen to a tape recording of a passage and then measured their *recognition memory* to determine whether they remembered the exact wording of sentences in the passage or just the general meaning of the passage.



➤ **Figure 6.7** Results of the Wickens et al. (1976) proactive interference experiment. (a) The Fruits group showed reduced performance on trials 2, 3, and 4, caused at least partially by proactive interference (indicated by blue points). (b) The Professions group showed similarly reduced performance on trials 2 and 3. The increase in performance on trial 4 represents a release from proactive interference because the names of fruits, rather than professions, were presented on trial 4.

(Source: Based on D. D. Wickens, R. E. Dalezman, & F. T. Eggemeier, Multiple encoding of word Attributes in memory, Memory & Cognition, 4, 307–310, 1976.)

METHOD Measuring Recognition Memory

Recognition memory is the identification of a stimulus that was encountered earlier. The procedure for measuring recognition memory is to present a stimulus during a study period and later to present the same stimulus along with others that were not presented. For example, in the study period, a list of words might be presented that includes the word *house*. Later, in the test, a series of words is presented that includes *house* plus some other words that were not presented, such as *table* and *money*. The participant's task is to answer "Yes" if the word was presented previously (the word *house* in this example) and "No" if it wasn't presented (the words *table* and *money*). Notice that this method is different from testing for *recall* (see Method: Recall, Chapter 5, page 138). In a recall test, the person must *produce* the item to be recalled. An example of a recall test is a fill-in-the-blanks exam question. In contrast, an example of recognition is a multiple-choice exam, in which the task is to pick the correct answer from a number of alternatives. The way Sachs applied recognition to the study of coding in LTM is illustrated in the next demonstration.

DEMONSTRATION Reading a Passage

Read the following passage:

> There is an interesting story about the telescope. In Holland, a man named Lippershey was an eyeglass maker. One day his children were playing with some lenses. They discovered that things seemed very close if two lenses were held about a foot apart. Lippershey began experimenting, and his "spyglass" attracted much attention. He sent a letter about it to Galileo, the great Italian scientist. Galileo at once realized the importance of the discovery and set about building an instrument of his own.

Now cover up the passage and indicate which of the following sentences is identical to a sentence in the passage and which sentences are changed.

He sent a letter about it to Galileo, the great Italian scientist.
Galileo, the great Italian scientist, sent him a letter about it.
A letter about it was sent to Galileo, the great Italian scientist.
He sent Galileo, the great Italian scientist, a letter about it.

Which sentence did you pick? Sentence (1) is the correct answer because it is the only one that is identical to one in the passage. The task facing Sachs's participants was more difficult, because they heard a passage two or three times as long, so there was more material to remember and there was a longer delay between hearing the sentence and being asked to remember it. Many of Sachs's participants correctly identified sentence (1) as being identical and knew that sentence (2) was changed. However, a number of people identified sentences (3) and (4) as matching one in the passage, even though the wording was different. These participants apparently remembered the sentence's meaning but not its exact wording. The finding that specific wording is forgotten but the general meaning can be remembered for a long time has been confirmed in many experiments. This description in terms of meaning is an example of semantic coding in LTM.

Comparing Coding in Short-Term and Long-Term Memory

We have seen that information can be represented in both STM and LTM in terms of vision (visual coding), hearing (auditory coding), and meaning (semantic coding) (**Table 6.2**). The type of coding that occurs in a particular situation depends largely on the task. Consider, for example, the task of remembering a telephone number that you have just heard. One way of maintaining the number in memory is by repeating it over and over—an example of auditory coding. It is less likely that you would remember the number in terms of either its visual image or the meaning of the phone number. Because of the nature of many STM tasks, auditory coding is the predominant type of coding in STM.

Now consider another example. You finished reading an adventure story last week and are now remembering what you read. It is unlikely that you remember what the words looked like as you were reading them, but you are more likely to remember what happened in the story. Remembering what happened is semantic coding, which often occurs for LTM. If in remembering the story you conjured up images of some of the places you imagined as you read the story (or perhaps saw, if the book included illustrations), this would be an

TABLE 6.2
Examples of Coding in Short-Term and Long-Term Memory

Code	Short-Term Memory	Long-Term Memory
Visual	Holding an image in the mind to reproduce a visual pattern that was just seen (Della Sala et al., 1999.)	Visualizing what the Lincoln Memorial in Washington, D.C., looked like when you saw it last summer
Auditory	Representing the sounds of letters in the mind just after hearing them (Conrad, 1964)	Repeating a song you have heard many times before, over and over in your mind
Semantic	Placing words in an STM task into categories based on their meaning (Wickens et al., 1976)	Recalling the general plot of a novel you read last week (Sachs)

example of visual coding in LTM. Generally, semantic coding is the most likely form of coding for LTM tasks.

Locating Memory in the Brain

At the end of Chapter 5, we saw that the prefrontal cortex and other areas are involved in working memory (Figure 5.19, page 150). Our goal in this section is to describe some experiments that compare where STM and LTM are represented in the brain. We will see that there is evidence that STM and LTM are separated in the brain, but also some evidence for overlap. The strongest evidence for separation is provided by neuropsychological studies.

Neuropsychology In 1953, Henry Molaison (known as patient HM until his death at the age of 82 in 2008) underwent an experimental procedure designed to eliminate his severe epileptic seizures. The procedure, which involved removal of HM's **hippocampus** (see Figure 5.19) on both sides of his brain, succeeded in decreasing his seizures but had the unintended effect of eliminating his ability to form new long-term memories (Corkin, 2002; Scoville & Milner, 1957).

HM's short-term memory remained intact, so he could remember what had just happened, but he was unable to transfer any of this information into long-term memory. One result of this inability to form new long-term memories was that even though psychologist Brenda Milner tested him many times over many decades, HM always reacted to her arrival in his room as if he were meeting her for the first time. HM's case, although tragic for him personally, led to an understanding of the role of the hippocampus in forming new long-term memories. Furthermore, the fact that his short-term memory remained intact suggested that short-term and long-term memories are served by separate brain regions (also see Suddendorf et al., 2009; Wearing, 2005 for a description of another case of hippocampus damage causing loss of the ability to form long-term memories).

There are also people with a problem opposite to that of HM—that is, they have normal LTM but poor STM. One example is patient KF, who had suffered damage to his parietal lobe in a motorbike accident. KF's poor STM was indicated by a reduced digit span—the number of digits he could remember (see page 138; Shallice & Warrington, 1970). Whereas the typical span is between five and nine digits, KF had a digit span of two; in addition, the recency effect in his serial position curve, which is associated with STM, was reduced. Even though KF's STM was greatly impaired, he had a functioning LTM, as indicated by his ability to form and hold new memories of events in his life.

What's special about these cases together is that because HM had intact STM but wasn't able to form new long-term memories and KF had the opposite problem (intact LTM but a deficient STM), they establish a double dissociation (see Method: Demonstrating a Double Dissociation, page 40) between STM and LTM (**Table 6.3**). This evidence supports the idea that STM and LTM are caused by different mechanisms, which can act independently.

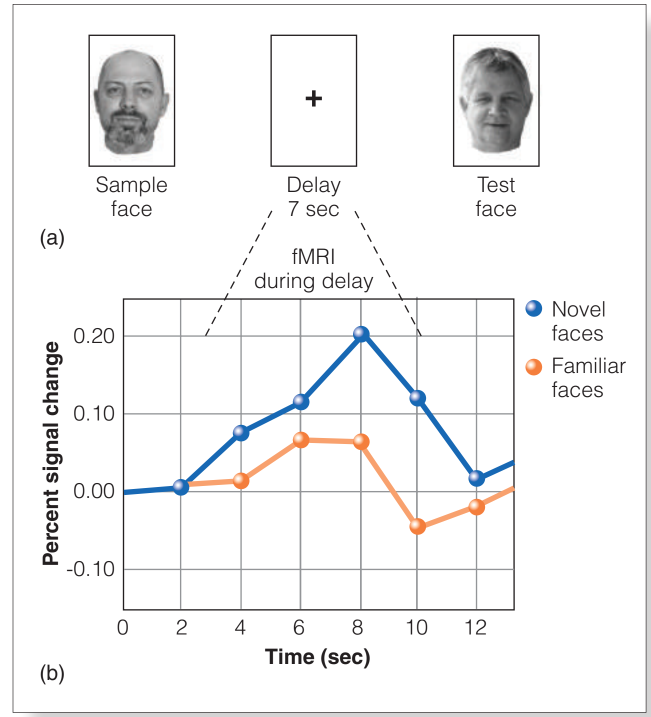
TABLE 6.3
A Double Dissociation for Short-Term and Long-Term Memory

Patient	Short-Term Memory	Long-Term Memory
HM	OK	Impaired
KF	Impaired	OK

The combination of the neuropsychological evidence and the results of behavioral experiments such as those measuring the serial position curve, as well as the proposal of the modal model in which STM and LTM are represented by separate boxes, supports the idea of the separation of STM and LTM. However, some recent brain imaging experiments show that this separation is not so straightforward.

Brain Imaging Charan Ranganath and Mark D'Esposito (2001) asked whether the hippocampus, which is crucial for forming new long-term memories, might also play a role in holding information for short periods of time. **Figure 6.8a** shows the sequence of stimuli presented to participants as they were having their brain scanned. A sample face was presented for 1 second, followed by a 7-second delay period. Then a test face was presented, and the participant's task was to decide whether it matched the sample face. Participants were run in two conditions. In the "novel face" condition, they were seeing each face for the first time. In the "familiar face" condition, they saw faces that they had seen prior to the experiment.

The results, shown in **Figure 6.8b**, indicate that activity in the hippocampus increases as participants are holding novel faces in memory during the 7-second delay, but activity changes only slightly for the familiar faces. Based on this result, Ranganath and D'Esposito concluded that the hippocampus is involved in maintaining novel information in memory during short delays. Results such as these, plus the results of many other experiments, show that the hippocampus and other medial temporal lobe structures once thought to be involved only in LTM also play some role in STM (Cashdollar et al., 2009; Jonides et al., 2008; Nichols et al., 2006; Ranganath & Blumenfeld, 2005; Rose et al., 2012).



➤ **Figure 6.8** (a) Stimuli presentation for Ranganath and D'Esposito's (2001) experiment. (b) Hippocampus fMRI response increases during the delay for novel faces but only increases slightly for faces people had seen before. (Source: Based on C. Ranganath & M. D'Esposito, Medial temporal lobe activity associated with active maintenance of novel information, Neuron, 31, 865–873, 2001.)

Taking these new results into account, many researchers have concluded that although there is good evidence for the separation of short-term memory and long-term memory, there is also evidence that these functions are not as separated as previously thought, especially for tasks involving novel stimuli. As we now shift our focus to considering only long-term memory, we will focus first on episodic and semantic long-term memory.

TEST YOURSELF 6.1

1. Describe how differences between STM and LTM have been determined by measuring serial position curves.
2. What are some examples of visual, auditory, and semantic coding for STM and for LTM?
3. Describe how Wickens and the Sachs experiments provide evidence for semantic coding in STM and LTM. What can we conclude about similarities and differences in STM and LTM based on the way coding occurs in both?
4. What conclusions about the separation of STM and LTM followed from neuropsychology studies involving HM and KF?
5. What do more recent experiments, such as the one by Ranganath and D'Esposito, indicate about the separation between brain mechanisms serving STM and LTM?

Episodic and Semantic Memory

We are now ready to leave short-term memory behind and ask why episodic memory (memory for experiences) and semantic memory (memory for facts) are considered to be two different types of memory. This question has been answered by considering (1) the type of *experience* associated with episodic and semantic memories, (2) how brain damage affects each one, and (3) the fMRI responses to each one.

Distinctions Between Episodic and Semantic Memory

When we say that episodic memory is memory for experiences and that semantic memory is memory for facts, we are distinguishing between two types of memory based on the types of *information* remembered. Endel Tulving (1985), who first proposed that episodic and semantic memories handled different types of information, also suggested that episodic and semantic memory can be distinguished based on the type of *experience* associated with each (also see Gardiner, 2001; Wheeler et al., 1997).

Differences in Experience According to Tulving, the defining property of the experience of episodic memory is that it involves **mental time travel**—the experience of traveling back in time to reconnect with events that happened in the past. For example, I can travel back 20 years in my mind to remember cresting the top of a mountain near the California coast and seeing the Pacific Ocean far below, as it stretched into the distance. I remember sitting in the car, seeing the ocean, and saying, "Wow!" to my wife, who was sitting next to me. I also remember some of the emotions I was experiencing, and other details, such as the inside of my car, the sun reflecting off the water, and the expectation of what we were going to see on the way down the mountain. In short, when I remember this incident, I feel as if I am *reliving* it. Tulving describes this experience of mental time travel/episodic memory as *self-knowing* or *remembering*.

In contrast to the mental time travel property of episodic memory, the experience of semantic memory involves accessing knowledge about the world that does not have to be tied to remembering a personal experience. This knowledge can be things like facts, vocabulary, numbers, and concepts. When we *experience* semantic memory, we are not traveling back to a specific event from our past, but we are accessing things we are familiar with and know about. For example, I know many facts about the Pacific Ocean—where it is located, that it is big, that if you travel west from San Francisco you end up in Japan—but I can't remember exactly when I learned these things. The various things I know about the Pacific Ocean are semantic memories. Tulving describes the experience of semantic memory as *knowing*, with the idea that knowing does not involve mental time travel.

Neuropsychological Evidence Just as neuropsychological evidence was used to distinguish between STM and LTM, it has also been used to distinguish between episodic and semantic memory. We first consider the case of KC, who at the age of 30 rode his motorcycle off a freeway exit ramp and suffered severe damage to his hippocampus and surrounding structures (Rosenbaum et al., 2005). As a result of this injury, KC lost his episodic memory—he can no longer relive any of the events of his past. He does, however, know that certain things happened, which would correspond to semantic memory. He is aware of the fact that his brother died 2 years ago but remembers nothing about personal experiences such as how he heard about his brother's death or what he experienced at the funeral. KC also remembers facts like where the eating utensils are located in the kitchen and the difference between a strike and a spare in bowling. Thus, KC has lost the episodic part of his memory, but his semantic memory is largely intact. (Also see Palombo et al., 2015 for more case histories of people who have no episodic memory but good semantic memory.)

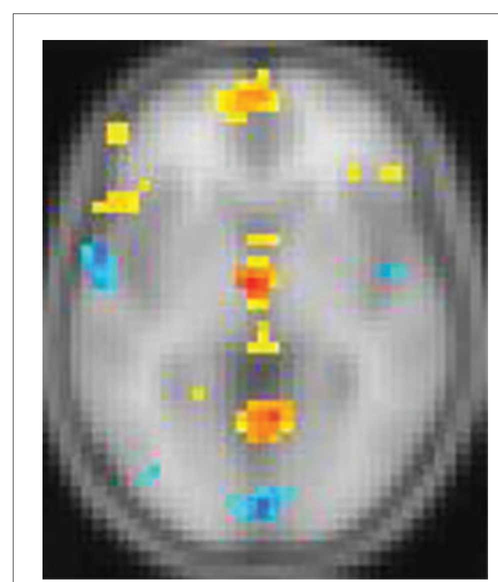
TABLE 6.4
A Double Dissociation for Semantic and Episodic Memory

Patient	Semantic Memory	Episodic Memory
KC	OK	Poor
LP	Poor	OK

A person whose brain damage resulted in symptoms opposite to those experienced by KC is LP, an Italian woman who was in normal health until she suffered an attack of encephalitis at the age of 44 (DeRenzi et al., 1987). The first signs of a problem were headaches and a fever, which were later followed by hallucinations lasting for 5 days. When she returned home after a 6-week stay in the hospital, she had difficulty recognizing familiar people; she had trouble shopping because she couldn't remember the meaning of words on the shopping list or where things were in the store; and she could no longer recognize famous people or recall facts such as the identity of Beethoven or the fact that Italy was involved in World War II. All of these are semantic memories.

Despite this severe impairment of memory for semantic information, she was still able to remember events in her life. She could remember what she had done during the day and things that had happened weeks or months before. Thus, although she had lost semantic memories, she was still able to form new episodic memories. **Table 6.4** summarizes the two cases we have described. These cases, taken together, demonstrate a double dissociation between episodic and semantic memory, which supports the idea that memory for these two different types of information probably involves different mechanisms.

Although the double dissociation shown in Table 6.4 supports the idea of separate mechanisms for semantic and episodic memory, interpretation of the results of studies of brain-damaged patients is often tricky because the extent of brain damage often differs from patient to patient. In addition, the method of testing patients may differ in different studies. It is important, therefore, to supplement the results of neuropsychological research with other kinds of evidence. This additional evidence is provided by brain imaging experiments. (See Squire & Zola-Morgan, 1998, and Tulving & Markowitsch, 1998, for further discussion of the neuropsychology of episodic and semantic memory.)



➤ **Figure 6.9** Brain showing areas activated by episodic and semantic memories. The yellow areas represent brain regions associated with episodic memories; the blue areas represent regions associated with semantic memories. (Source: Levine et al., 2004)

Brain Imaging Brian Levine and coworkers (2004) did a brain imaging experiment in which they had participants keep diaries on audiotape describing everyday personal events (example: "It was the last night of our Salsa dance class. . . . People were dancing all different styles of Salsa. . . .") and facts drawn from their semantic knowledge ("By 1947, there were 5,000 Japanese Canadians living in Toronto"). When the participants later listened to these audiotaped descriptions while in an fMRI scanner, the recordings of everyday events elicited detailed episodic autobiographical memories (people remembered their experiences), while the other recordings simply reminded people of semantic facts.

Figure 6.9 shows brain activation in a cross-section of the brain. The yellow areas represent brain regions associated with episodic memories; the blue areas represent brain regions associated with semantic, factual knowledge (personal and nonpersonal). These results and others indicate that although there can be overlap between activation caused by episodic and semantic memories, there are also major differences (also see Cabeza & Nyberg, 2000; Duzel et al., 1999; Nyberg et al., 1996).

The fact that we can draw distinctions between episodic and semantic memory doesn't mean, however, that they operate totally separately from one another. In keeping with this chapter's theme of *division and interaction*, we will now see that there is a great deal of interaction between these two systems.

Interactions Between Episodic and Semantic Memory

In real life, episodic and semantic memories are often intertwined. Two examples are (1) how knowledge (semantic) affects experience (episodic) and (2) the makeup of autobiographical memory.

Knowledge Affects Experience We bring a vast store of knowledge with us as we are having the experiences we will later remember. For example, I recently was watching a baseball game with a friend who was British and had never been to a baseball game, so his knowledge was limited to the basic principle that the point of the game is to hit the ball, run the bases, and score runs. As we sat watching the game together, I soon realized that I knew many things about the game that I take for granted. At one point in the game, when there was a man on first and one out, I was anticipating the possibility that a ground ball might result in a double play. Then, when the batter hit a ground ball to the third baseman, I immediately looked to second base, where the third baseman threw the ball for one out, and then to first, where the second baseman threw for the second out. Meanwhile, my British friend's reaction was "What happened?" Clearly, my knowledge of the game influenced what I paid attention to and how I experienced the game. Our knowledge (semantic memory) guides our experience, and this, in turn, influences the episodic memories that follow from that experience.

Autobiographical Memory Has Both Semantic and Episodic Components The interplay between episodic and semantic memory also occurs when we consider **autobiographical memory**—memory for specific experiences from our life, which can include both episodic and semantic components. For example, consider the following autobiographical memory: "When I met Gil and Mary at the Le Buzz coffee shop yesterday, we sat at our favorite table, which is located near the window, but which is hard to get in the morning when Le Buzz is busy."

Notice that this description contains episodic components (meeting Gil and Mary yesterday is a specific experience) and semantic components (Le Buzz is a coffee shop; the table near the window is our favorite one; that table is difficult to get in the morning are all facts). The semantic components of this description are called **personal semantic memories** because they are facts associated with personal experiences (Renoult et al., 2012). **Table 6.5** summarizes the characteristics of episodic, semantic, and autobiographical memories.

Another interaction between episodic and semantic memory has been demonstrated in an experiment by Robyn Westmacott and Morris Moscovitch (2003), which showed that people's knowledge about public figures, such as actors, singers, and politicians, can include both semantic and episodic components. For example, if you know some facts about Oprah Winfrey and that she had a television program, your knowledge would be mainly semantic. But if you can remember watching some of her television shows, or, better yet, were in the studio audience during one of her shows, your memory for Oprah Winfrey would have episodic components.

Westmacott and Moscovitch call semantic memories involving personal episodes *autobiographically significant* semantic memories. When they tested people's ability to remember the names of public figures, they found that recall was better for names of people who had higher autobiographical significance. Thus, you would be more likely to recall the name of a popular singer (semantic information) if you had attended one of his or her concerts (episodic experience) than if you just knew about the singer because he or she was a famous person.

TABLE 6.5
Types of Long-Term Memory

Type	Definition	Example
Episodic	Memory for specific personal experiences, involving mental time travel back in time to achieve a feeling of reliving the experience.	I remember going to get coffee at Le Buzz yesterday morning and talking with Gil and Mary about their bike trip.
Semantic	Memory for facts.	There is a Starbucks down the road from Le Buzz.
Autobiographical	People's memories for experiences from their own lives. These memories have both episodic components (relived specific events) and semantic components (facts related to these events). These semantic components of autobiographical memory are *personal semantic memories*.	I met Gil and Mary at Le Buzz yesterday morning. We sat at our favorite table near the window, which is often difficult to get in the morning when the coffee shop is busy.

What this means is that experiences related to episodic memories can aid in accessing semantic memories. Interestingly, when Westmacott and coworkers (2003) ran the same experiment on people with brain damage who had lost their episodic memory, there was no enhanced memory for autobiographically significant names. Thus, when episodic memory is present, semantic memory for "facts" (like a person's name) is enhanced. But when episodic memory is absent, this advantage created by personally relevant facts vanishes—another example of the interrelatedness of episodic and semantic memory.

This connection between episodic and semantic memory becomes even more interesting when we ask what happens to long-term memories with the passage of time. Remember that STM lasts only about 15 seconds (unless information is held there by rehearsal), so events we remember from an hour, a day, or a year ago are all remembered from LTM. However, as we will now see, not all long-term memories are created equal. We are more likely to remember the details of something that happened yesterday than something that happened a year ago, and we may later forget something that happened yesterday while still remembering what happened a year ago!

What Happens to Episodic and Semantic Memories as Time Passes?

One procedure for determining what happens to memory as time passes is to present stimuli and then, after some time passes, ask a participant to recall stimuli, as in the serial position curve experiments (page 164) or recognition experiments in which participants are asked to recognize a sentence from a passage they had read (page 168). The typical result of these experiments is that participants forget some of the stimuli, with forgetting increasing at longer time intervals. But when we consider the process of forgetting in more detail, we see that forgetting is not always an "all-or-nothing" process. For example, consider the following situation: A friend introduces you to Roger at the coffee shop on Monday, and you talk briefly. Then later in the week, you see Roger across the street. Some possible reactions to seeing Roger are:

That person looks familiar. What's his name and where did I meet him?
There's Roger. Where did I meet him?
There's Roger, who I met at the coffee shop last Monday. I remember talking with him about football.

It is clear that there are different degrees of forgetting and remembering. The first two examples illustrate *familiarity*—the person seems familiar and you might remember his name, but you can't remember any details about specific experiences involving that person. The last example illustrates *recollection*—remembering specific experiences related to the person. Familiarity is associated with semantic memory because it is not associated with the circumstances under which knowledge was acquired. Recollection is associated with episodic memory because it includes details about what was happening when knowledge was acquired plus an awareness of the event as it was experienced in the past. These two ways of remembering have been measured using the **remember/know procedure**.

METHOD Remember/Know Procedure

In the remember/know procedure, participants are presented with a stimulus they have encountered before and are asked to respond with (1) *remember* if the stimulus is familiar and they also remember the circumstances under which they originally encountered it; (2) *know* if the stimulus seems familiar but they don't remember experiencing it earlier; or (3) *don't know* if they don't remember the stimulus at all. This procedure has been used in laboratory experiments in which participants are asked to remember lists of stimuli, and has also been used to measure people's memory for actual events from the past. This procedure is important because it distinguishes between the episodic components of memory (indicated by a *remember* response) and semantic components (indicated by a *know* response).

Raluca Petrican and coworkers (2010) determined how people's memory for public events changes over time by presenting descriptions of events that had happened over a 50-year period to older adults (average age = 63 years) and asking them to respond with *remember* if they had a personal experience associated with the event or recollected seeing details about the event on TV or in the newspaper. They were to respond *know* if they were familiar with the event but couldn't recollect any personal experience or details related to media coverage of the event. If they couldn't remember the event at all, they were to respond *don't know*.

The results of this experiment are shown in **Figure 6.10**, which indicates memory for public events that happened within the most recent 10 years, and memory for events that happened 40 to 50 years earlier. (Intermediate delays were also tested in the experiment. We are focusing on the extremes.) As would be expected, complete forgetting increased over time (red bars). But the interesting result is that *remember* responses decreased much more than *know* responses, meaning that memories for 40- to 50-year-old events had lost much of their episodic character. This result illustrates the **semanticization of remote memories**—loss of episodic detail for memories of long-ago events.

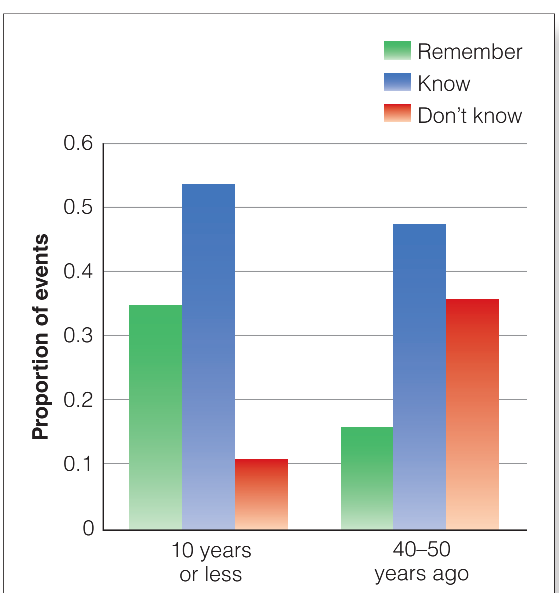


Figure 6.10 Results of the remember/know experiment that tested older subjects' memory for events over a 50-year period.

(Source: Based on R. Petrican, N. Gopie, L. Leach, T. W. Chow, B. Richards, & M. Moscovitch, Recollection and familiarity for public events in neurologically intact older adults and two brain-damaged patients. Neuropsychologia, 48, 945–960, 2010.)

This loss of episodic details has been demonstrated both for long-ago events, as in the Petrican experiment, and also for periods as short as 1 week (Addis et al., 2008; D'Argembeau & Van der Linden, 2004; Johnson et al., 1988; Viskontas et al., 2009). This shorter-term semanticization makes sense when we consider personal experiences. You probably remember the details of what you did earlier today or yesterday but fewer details about what happened a week ago (unless what happened a week ago was particularly important).

Another way to appreciate the semanticization of remote memories is to consider how you have acquired the knowledge that makes up your semantic memories. When you were in the sixth grade, you may have learned that the legislative branch of the U.S. government consists of the Senate and the House of Representatives. Right after learning this, you might have found it easy to remember what was going on in class, including what the classroom looked like, what the teacher was saying, and so on. Remembering all these details about the circumstances of learning comes under the heading of episodic memory. The facts about how the government works is semantic memory.

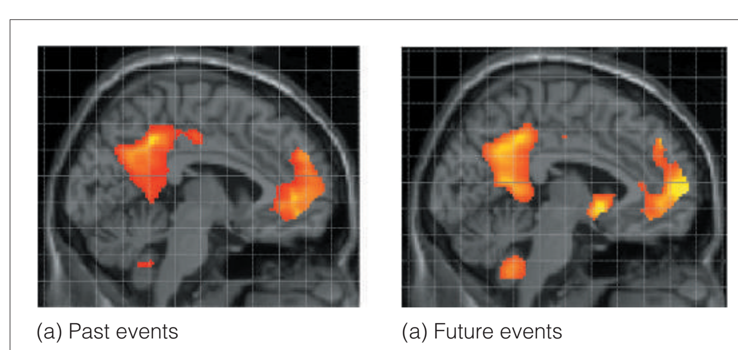
Many years later, in college, your semantic memory about the structure of the U.S. government remains, but the episodic details about what was happening on the specific day you learned that information are probably gone. Thus, the knowledge that makes up your semantic memories is initially attained through personal experiences that are the basis of episodic memories, but your memory for these experiences often fades, and only semantic memory remains.

Back to the Future

We usually think of memory in terms of bringing back events or facts from the past. But what about imagining what might happen in the future? Is there a connection between the two? William Shakespeare's line, "What's past is prologue," from *The Tempest*, draws a direct connection between the past, the present, and perhaps the future. Steve Jobs, one of the founders of Apple Computer, comments on the connection by noting, "You can't connect the dots looking forward; you can only connect them looking backwards; so you have to trust that the dots will somehow connect in your future" (Jobs, 2005).

Extending the dots into the future has become an important topic of memory research. This research doesn't ask how well we can *predict* the future, but asks how well we can create possible scenarios *about* the future. The reason this has become a topic of research is that there is evidence of a connection between the ability to remember the past and the ability to imagine the future. Evidence for this connection is provided by patients who have lost their episodic memory as a result of brain damage. KC, the motorcyclist we described earlier as having lost his episodic memory because of a head injury, was unable to use his imagination to describe personal events that might happen in the future (Tulving, 1985). Another patient, DB, who had difficulty recalling past events because of damage to his hippocampus, also had difficulty imagining future events. His inability to imagine future events was restricted to things that might happen to him personally; he could still imagine other future events, such as what might happen in politics or other current events (Addis et al., 2007; Hassabis et al., 2007; Klein et al., 2002).

This behavioral evidence for a link between the ability to remember the past and the ability to imagine what might happen in the future led Donna Rose Addis and coworkers (2007) to look for a physiological link by using fMRI to determine how the brain is activated by remembering the past and imagining the future. Brain activation was measured as neurologically normal participants silently thought about either events from the past or events that might happen in the future. The results indicated that all the brain regions that were active while thinking about the past were also active while thinking about the future (**Figure 6.11**). These results suggest that similar neural mechanisms are involved in remembering the past and predicting the future (Addis et al., 2007, 2009; Schacter & Addis, 2009). Based on these results, Schacter and Addis (2007, 2009) proposed the **constructive episodic simulation hypothesis**, which states that episodic memories are extracted and recombined to construct simulations of future events.



➤ **Figure 6.11** Brain activation caused by (a) thinking about past events and (b) imagining future events. (Source: Addis et al., 2007)

(a) First-person perspective

(b) Third-person perspective

Bruce Goldstein

➤ **Figure 6.12** Two ways of visually remembering an event: (a) First-person perspective. Event is remembered as it would have been seen by the person doing the remembering. (b) Third-person perspective. Event is remembered as it would be seen by an outside observer looking at the event. In this third-person view, the person doing the remembering is the woman in black.

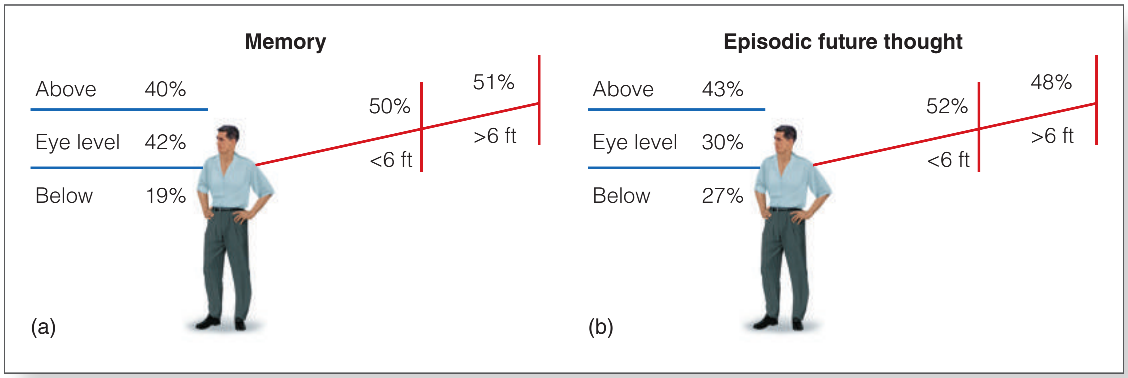
The idea that there is a connection between imagining the past and predicting the future is also supported by an experiment by Eleanor McDermott and coworkers (2016), in which participants were asked to remember an event from the past or to imagine a similar event that might happen in the future. Participants were also told to describe what they were seeing as they remembered or imagined, and to notice whether their observation was from a first-person perspective (what they would see if they were a participant in the event, as in **Figure 6.12a**) or from a third-person perspective (what they would see if they were an outside observer watching the event happen, as in **Figure 6.12b**). When compared in this way, both remembered and imagined events were more likely to be "seen" from a third-person perspective, although there were slightly fewer third-person perceptions for the remembered past (71 percent) than for the imagined future (78 percent).

McDermott also noted the visual viewpoint of her participant's reports. These results, in **Figure 6.13**, show that there are some differences, with more below eye-level and fewer eye-level responses for the imagined future condition. But the above eye-level responses and the distances were the same. Based on the overlap between the results for memories and imagined futures, McDermott concluded that it is likely that common processes are involved in both situations.

Why is it important to be able to imagine the future? One answer to that question is that when the future becomes the present, we need to be able to act effectively. Considered in this way, being able to imagine the future becomes very important, and, in fact, Donna Rose Addis and coworkers (2007) have suggested that perhaps the main role of the episodic memory system is not to remember the past but to enable people to simulate possible future scenarios in order to help anticipate future needs and guide future behavior. This could be useful, for example, in deciding whether to approach or avoid a particular situation, both of which could have implications for effectively dealing with the environment and, perhaps, even for survival (Addis et al., 2007; Schacter, 2012).

The idea that simulating the future might be an adaptive process brings us back to the phenomenon of mind wandering, which we discussed in Chapter 2 (p. 51) and Chapter 4 (p. 114). We saw that mind wandering (1) is associated with activation of the default mode network (DMN), which becomes active when a person isn't focused on a specific task (p. 50) and (2) is extremely prevalent, occurring as much as half the time during waking hours (p. 114). We also noted that mind wandering can cause decreases in performance on tasks that require focused attention (p. 114), but that mind wandering is likely to have positive effects as well.

One hint at a positive role for mind wandering is that when mind wandering occurs, people are more likely to think about the future than about the past or the present (Baird et al., 2011). This has led some researchers to suggest that one of the reasons that the mind wanders is to help people plan for the future by helping create simulations of the future from our episodic memories. And to make this story about mind wandering, DMN activity, and planning for the future even more interesting, recent research has shown that damage to the DMN can cause problems in retrieving autobiographical memories (Philippi et al., 2015), which, as we have seen from the cases KC and DB, is associated with problems in imagining future events.



➤ **Figure 6.13** Points of view for third-person perspectives for (a) memory of a past event; (b) imagining a possible future event. The red numbers indicate percentages of views from above eye level, at eye level, and below eye level. The orange numbers indicate percentages of views that were less than or more than 6 feet away.

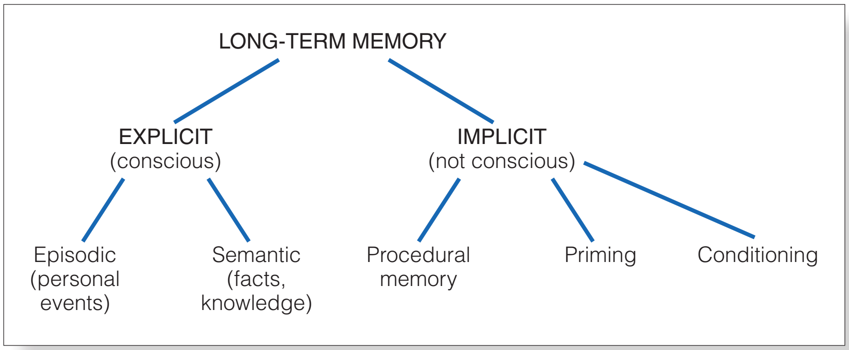
(Source: McDermott et al., 2016 Fig. 3, p. 248)

TEST YOURSELF 6.2

1. How have episodic and semantic memory been distinguished from one another? Consider both the definitions and Tulving's idea of mental time travel.
2. Describe neuropsychological evidence for a double dissociation between episodic and semantic memory.
3. Describe Levine's "diary" experiment. What do the brain imaging results indicate about episodic and semantic memory?
4. Describe how knowledge (semantic) can affect experience (episodic).
5. What is autobiographical memory? How does the definition of autobiographical memory incorporate both episodic and semantic memory?
6. Describe how personal significance can make semantic memories easier to remember. What happens to the "personal significance effect" in people who have lost their episodic memories due to brain damage?
7. Describe what happens to memory as time passes. What is the semanticization of episodic memory?
8. What is the remember/know procedure? How does it distinguish between episodic and semantic memories? How has it been used to measure how memory changes over time?
9. Describe the following evidence that indicates overlap between episodic memory for the past and the ability to imagine future events: (1) memory of people who have lost their episodic memory; (2) brain imaging evidence.
10. What is the constructive episodic simulation hypothesis? Describe McDermott's experiment in which she compared the perspectives and viewpoints that people take when remembering the past and imagining the future.
11. What role does Addis and coworkers suggest for episodic memory?

Procedural Memory, Priming, and Conditioning

Figure 6.14 is a diagram of the different types of long-term memory. We have been focusing so far on the two types of memory shown on the left, episodic and semantic, which fall under the heading of *explicit memory*. **Explicit memories** are memories we are aware of.



➤ **Figure 6.14** Long-term memory can be divided into explicit memory and implicit memory. We can also distinguish between two types of explicit memory, episodic and semantic. There are a number of different types of implicit memory. Three of the main types are procedural memory, priming, and conditioning.

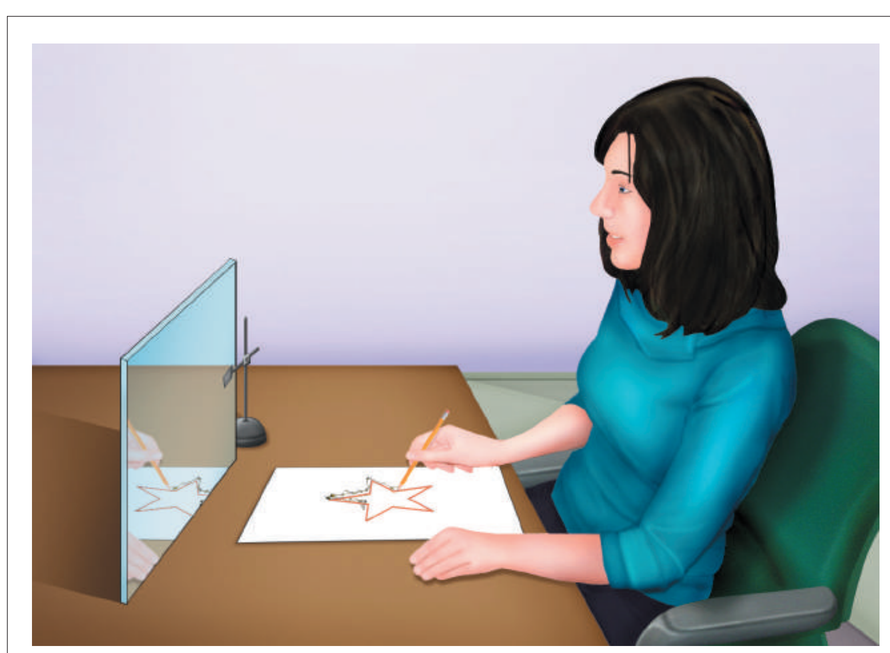
This may seem like a strange statement, because aren't we aware of all of our memories? We tell someone about our vacation or give directions to a lost traveler, and not only are we aware of our memories (episodic for describing the vacation; semantic for knowing the directions), but we are making someone else aware of our memories.

But there are, in fact, memories we aren't aware of, called **implicit memories**, shown on the right side of the diagram. Implicit memory occurs when learning from experience is not accompanied by conscious remembering. For example, we do many things without being able to explain how we do them. These abilities come under the heading of *procedural memories*.

Procedural Memory

Procedural memory is also called **skill memory** because it is memory for doing things that usually involve learned skills.

The Implicit Nature of Procedural Memory The implicit nature of procedural memory has been demonstrated in patients like LSJ, a skilled violinist who suffered a loss of episodic memory due to damage to her hippocampus caused by encephalitis, but who could still play the violin (Valtonen et al., 2014). Amnesiac patients can also master new skills even though they don't remember any of the practice that led to this mastery. For example, HM, whose amnesia was caused by having his hippocampus removed (see page 170), practiced a task called *mirror drawing*, which involves copying a picture that is seen in a mirror (**Figure 6.15**). You can appreciate this task by doing the following demonstration.



➤ **Figure 6.15** Mirror drawing. The task is to trace the outline of the star while looking at its image in the mirror.

DEMONSTRATION Mirror Drawing

Draw a star like the one in **Figure 6.15** on a piece of paper. Place a mirror or some other reflective surface (some cell phone screens work) about an inch or two from the star, so that the reflection of the star is visible. Then, while looking at the reflection, trace the outline of the star on the paper (no fair looking at the actual drawing on the paper!). You will probably find that the task is difficult at first but becomes easier with practice.

After a number of days of practice, HM became quite good at mirror drawing, but because his ability to form long-term memories was impaired, he always thought he was practicing mirror drawing for the first time. HM's ability to trace the star in the mirror, even though he couldn't remember having done it before, illustrates the implicit nature of procedural memory. Another example of practice improving performance without any recollection of the practice is the violinist LSJ, mentioned earlier, whose performance improved as she practiced a new piece of music, but who had no memory of practicing the piece (Gregory et al., 2016; Valtonen et al., 2014).

KC provides another example of a person who can't form new long-term memories but who can still learn new skills. After his motorcycle accident, he learned how to sort and stack books in the library. Even though he doesn't remember learning to do this, he can still do it, and his performance improves with practice. The fact that people with amnesia can retain skills from the past and learn new ones has led to an approach to rehabilitating patients with amnesia by teaching them tasks, such as sorting mail or performing repetitive computer-based tasks, that they can become expert at, even though they can't remember their training (Bolognani et al., 2000; Clare & Jones, 2008).

Our examples of implicit memories have so far included motor skills that involve movement and muscle action. You have also developed many purely cognitive skills that qualify as procedural memory. Consider, for example, your ability to have a conversation. Although you may not be able to describe the rules of grammar, that doesn't stop you from having a grammatically correct conversation. Beginning when we are infants, we learn to apply the rules of grammar, without necessarily being able to state the rules (although later, when we are older, we may study them).

Procedural Memory and Attention The main effect of procedural memories is that they enable us to carry out skilled acts without thinking about what we are doing. For example, consider what happens when a person is learning to play the piano. They may begin by paying close attention to their fingers striking the keys, being careful to play the correct note in the correct sequence. But once they become an expert pianist, their best strategy is to just play, without paying attention to their fingers. In fact, as we noted in Chapter 4, concert pianists report that when they become conscious of how they are moving their fingers while playing a difficult passage, they are no longer able to play the passage.

An interesting outcome of the fact that well-learned procedural memories do not require attention is an effect called **expert-induced amnesia**. Here's how it works: An expert, who is extremely well practiced at a particular skill, carries out the action. It is so well practiced that it happens automatically, much like a concert pianist's fingers move almost magically across the keys. The result of this automatic action is that when asked about what they did in carrying out a skilled action, the expert often has no idea.

An example of expert-induced amnesia in sports happened when the hockey player Sidney Crosby was being interviewed on the ice with a reporter for the TSN hockey network immediately following his overtime goal, which won the 2010 Olympic Gold Medal for Canada in men's ice hockey (**Figure 6.16**). The reporter asked Crosby, "Sid, if you can,

Jamie Squire/Getty Images Sport/Getty Images

➤ **Figure 6.16** Sidney Crosby, in white, scoring the winning goal for Canada in the 2010 Olympics.

just take us through how that goal went in." Crosby's reply: "I don't really remember. I just shot it—I think from around here. That's all I really remember. I think it went 5-hole,[1] but um, I didn't really see it to be honest." It is likely that the over 16 million Canadians who watched Crosby's goal could have described what he did in much more detail than Crosby, who, because he was "on automatic" during the play that scored the goal, wasn't sure exactly what happened.

A Connection between Procedural Memory and Semantic Memory Before leaving procedural memory, let's return to our violin player LSJ. Early research on LSJ noted that she had not only lost her ability to remember past events in her life, but that she had also lost her knowledge of the world. Even though she was a professional artist (in addition to being a violin player), she was unable to identify artists who painted famous works of art like Van Gogh's *Starry Night*. When presented with 62 well-known paintings, art-knowledgeable people in a control group named 71 percent of the paintings correctly, but LSJ named only 2 percent correctly (Gregory et al., 2014).

What does this have to do with procedural memory? It turns out that further testing of LSJ revealed an interesting result: Although she had lost most of her knowledge of the world, she was able to answer questions related to things that involved procedural memory. For example, she could answer questions such as "When you are painting with watercolor, how might you remove excess pain?" or "How is an acrylics brush different from a watercolor brush?" The same result also occurred when LSJ was asked questions about music ("Which instruments usually make up a string orchestra?"), driving ("How many sides does a stop sign have?"), and aviation—she was an expert pilot along with being a musician and an artist! ("What is the landing gear configuration for the Piper Cub?). The fact that LSJ remembers facts about how to do things demonstrates a link between semantic memory and memory involving motor skills like painting, playing music, driving, and piloting a plane.

What does this link between procedural and semantic memory remind you of? Earlier in this chapter we discussed interactions between semantic memory and episodic memory. You are more likely to recall the name of a popular singer (semantic information) if you had attended one of his or her concerts (episodic experience) (page 174). Similarly, the case of LSJ shows how knowledge about different fields (semantic information) is linked to the ability to carry out various skills (procedural memory). Although we can draw diagrams like Figure 6.14, which differentiate between different types of memory, it is also important to realize that these types of memory interact with each other.

Priming

Priming occurs when the presentation of one stimulus (the priming stimulus) changes the way a person responds to another stimulus (the test stimulus). One type of priming, **repetition priming**, occurs when the test stimulus is the same as or resembles the priming stimulus. For example, seeing the word *bird* may cause you to respond more quickly to a later presentation of the word *bird* than to a word you have not seen, even though you may not remember seeing *bird* earlier. Repetition priming is called implicit memory because the priming effect can occur even though participants may not remember the original presentation of the priming stimuli.

[1]"5-hole" in hockey is the name for the space between the goalie's legs. So saying the shot went 5-hole means Crosby thought his shot went between the goalie's legs.

TEST YOURSELF 7.1

1. What is encoding? Retrieval? Why is each necessary for successful memory?
2. What is the difference between elaborative rehearsal and maintenance rehearsal in terms of (a) the procedures associated with each type of rehearsal and (b) their effectiveness for creating long-term memories?
3. What is levels of processing theory? Be sure you understand depth of processing, shallow processing, and deep processing. What would levels of processing theory say about the difference between maintenance rehearsal and elaborative rehearsal?
4. Give examples of how memory for a word can be increased by (a) forming visual images, (b) linking words to yourself, (c) generating the word during acquisition, (d) organizing information, (e) rating the word in terms of survival, and (f) practicing retrieval. What do these procedures have in common?
5. What is the testing effect?
6. What do the results of the procedures in question 5 indicate about the relationship between encoding and retrieval?

Effective Studying

How do you study? Students have developed numerous techniques, which vary depending on the type of material to be studied and what works for a particular student. When students are asked to describe their study techniques, the most popular are highlighting material in text or notes (Bell & Limber, 2010; Gurung et al., 2010) and rereading text or notes (Carrier, 2003; Karpicke et al., 2009; Wissman et al., 2012). Unfortunately, research has generally found that these popular techniques are not very effective (Dunlosky et al., 2013). Apparently, students use highlighting and rereading because they are easy to use, and because they are not aware of more effective methods. We will describe a number of ways of learning material that have been shown to be effective. Even if you think highlighting and rereading work for you, you might want to consider also using one or more of the following techniques the next time you study.

Elaborate

A process that helps transfer the material you are reading into long-term memory is elaboration—thinking about what you are reading and giving it meaning by relating it to other things that you know. This becomes easier as you learn more because what you have learned creates a structure on which to hang new information.

Techniques based on association, such as creating images that link two things, as in Figure 7.2, often prove useful for learning individual words or definitions. For example, there is a memory effect called *proactive interference*, which occurs when previously learned information interferes with learning new information. The effect of proactive interference is illustrated by what might happen when learning French vocabulary words makes it more difficult to learn a list of Spanish words a little later. How can you remember the term *proactive interference*? My solution was to think of a "pro" football player smashing everything in his path as he runs forward in time, to remind me that proactive interference is the past influencing the present. I no longer need this image to remember what proactive interference is, but it was helpful when I was first learning this concept.

Generate and Test

The results of research on the generation effect (page 194) indicate that devising situations in which you take an active role in creating material is a powerful way to achieve strong encoding and good long-term retrieval. And research on retrieval practice and the testing effect (page 197) indicates that repeatedly testing yourself on material you are studying pays dividends in improved memory.

Testing is actually a form of generation, because it requires active involvement with the material. If you were going to test yourself, how would you get the test questions? One way would be to use the questions that are sometimes provided in the book or study guide, such as the Test Yourself questions in this book. Another way is to make up questions yourself. Because making up the questions involves active engagement with the material, it strengthens encoding of the material. Research has shown that students who read a text with the idea of *making up* questions did as well on an exam as students who read a text with the idea of *answering* questions later, and both groups did better than a group of students who did not create or answer questions (Frase, 1975).

Research has shown that many students believe that reviewing the material is more effective than testing themselves on it, but when they do test themselves, it is usually to determine how they are doing, not as a tool to increase learning (Kornell & Son, 2009). As it turns out, self-testing accomplishes two things: It indicates what you know *and* increases your ability to remember what you know later.

Organize

The goal of organizing material is to create a framework that helps relate some information to other information to make the material more meaningful and therefore strengthen encoding. Organization can be achieved by making "trees," as in Figure 7.5, or outlines or lists that group similar facts or principles together.

Organization also helps reduce the load on your memory. We can illustrate this by looking at a perceptual example. If you see the black and white pattern in Figure 3.17 (page 72) as unrelated black and white areas, it is extremely difficult to describe what it is. However, once you've seen this pattern as a Dalmatian, it becomes meaningful and therefore much easier to describe and to remember (Wiseman & Neisser, 1974). Organization relates to the phenomenon of chunking that we discussed in Chapter 5. Grouping small elements into larger, more meaningful ones increases memory. Organizing material is one way to achieve this.

Take Breaks

Saying "Take breaks" is another way of saying "Study in a number of shorter study sessions rather than trying to learn everything at once," or "Don't cram." There are good reasons to say these things. Research has shown that memory is better when studying is broken into a number of short sessions, with breaks in between, than when it is concentrated in one long session, even if the total study time is the same. This advantage for short study sessions is called the **spacing effect** (Reder & Anderson, 1982; Smith & Rothkopf, 1984).

Another angle on taking breaks is provided by research that shows that memory performance is enhanced if sleep follows learning (page 214). Although sleeping to avoid studying is probably not a good idea, sleeping soon after studying can improve a process called consolidation (which we will discuss later in this chapter) and which results in stronger memories.

Avoid "Illusions of Learning"

One of the conclusions of both basic memory research and research on specific study techniques is that some study techniques favored by students may *appear* to be more effective than they actually are. For example, one reason for the popularity of rereading as a study technique is that it can create the illusion that learning is occurring. This happens because reading and rereading material results in greater *fluency*—that is, repetition causes the reading to become easier and easier. But although this enhanced ease of reading creates the illusion that the material is being learned, increased fluency doesn't necessarily translate into better memory for the material.

Another mechanism that creates the illusion of learning is the *familiarity effect*. Rereading causes material to become familiar, so when you encounter it a second or third time, there is a tendency to interpret this familiarity as indicating that you know the material. Unfortunately, recognizing material that is right in front of you doesn't necessarily mean that you will be able to remember it later.

Finally, beware of highlighting. A survey by Sarah Peterson (1992) found that 82 percent of students highlight study material, and most of them do so while they are reading the material for the first time. The problem with highlighting is that it seems like elaborative processing (you're taking an active role in your reading by highlighting important points), but it often becomes automatic behavior that involves moving the hand, but with little deep thinking about the material.

When Peterson compared comprehension for a group of students who highlighted and a group who didn't, she found no difference between the performance of the two groups when they were tested on the material. Highlighting may be a good first step for some people, but it is usually important to go back over what you highlighted using techniques such as elaborative rehearsal or generating questions in order to get that information into your memory.

Be An "Active" Note-Taker

The preceding study suggestions are about how to study course material, which typically means studying a textbook, course readings, and lecture notes. In addition to following these suggestions, another way to improve course learning is to think about how you go about creating your lecture notes. Do you take notes by writing them out by hand or by typing them into your laptop?

A majority of students report that they take notes on their laptop (Fried, 2008; Kay & Lauricella, 2011). When asked why they do this, their response is usually that typing notes on the laptop is more efficient, and that they can take more complete notes (Kay & Lauricella, 2011). Many professors, however, feel that taking notes on the laptop isn't a good idea because the laptop creates the temptation to engage in distracting activities like surfing the web or sending texts or emails. But in addition to this distraction argument against laptops, there is another argument against computer note taking: Computer note taking can result in shallower processing of the material, and therefore poorer performance on exams.

Empirical support for this idea has been provided by Pam Mueller and Daniel Oppenheimer (2014) in a paper titled "The Pen is Mightier Than the Keyboard: Advantages of Longhand Over Laptop Note Taking." They ran a number of experiments in which they had students listen to lectures and take notes either by longhand or by using their laptop. Laptop note-takers took more notes, because laptop note taking is easier and faster than note taking by hand. In addition, there were two other differences. The laptop notes contained more word-for-word transcription of the lecture, and students in the laptop group performed worse than the longhand group when tested on the lecture material.

Why did the laptop note-takers perform more poorly on the exam? Answering this question takes us back to the principle that memory for material depends on how it is encoded, and specifically that generating material yourself results in deeper processing and therefore better memory. According to Mueller and Oppenheimer, the shallow processing associated with simply transcribing what the professor is saying works against learning.

In contrast, creating hand-written notes are more likely to involve synthesizing and summarizing the lecture, which results in deeper encoding and better learning. The bottom-line message of the Mueller and Oppenheimer paper is that "active" and "involved" note taking is better than "mindless transcribing."

Adam Putnam and coworkers (2016), in a paper titled "Optimizing Learning in College: Tips from Cognitive Psychology," make many valuable suggestions regarding ways to succeed in college courses. Two of their suggestions, which are based on Mueller and Oppenheimer's results, are that in lecture courses, (1) "leave your laptop at home," to avoid the distraction of the Internet and social media, and (2) "write your notes instead of typing them," because handwriting encourages more reflective, deeper processing. Of course, Mueller and Oppenheimer are just one source, so before writing off computer note taking, it might be best to wait for the results of more research. But whatever mechanism you use to take notes, do your best to take notes in your own words, without simply copying what the lecturer is saying.

The message of all of these study hints is that there are ways to improve your learning by taking cues from the results of cognitive psychology research. The Putnam and coworkers, (2016) paper provides a concise summary of research-based conclusions about studying, and a paper by John Dunlosky and coworkers (2013) provides a more in-depth discussion, which ends by concluding that practice testing (see the upcoming section "Generate and Test") and distributed practice (see the preceding section "Take Breaks") are the two most effective study techniques.

Retrieval: Getting Information Out of Memory

We've already seen how retrieval can strengthen memory. But how can we increase the chances that something will be retrieved? The process of retrieval is extremely important because many of our failures of memory are failures of retrieval—the information is "in there," but we can't get it out. For example, you've studied hard for an exam but can't come up with an answer when you're taking the exam, only to remember it later after the exam is over. Or you unexpectedly meet someone you have previously met and can't recall the person's name, but it suddenly comes to you as you are talking (or, worse, after the person leaves). In both of these examples, you have the information you need but can't retrieve it when you need it.

Retrieval Cues

When we discussed how remembering the word *apple* might serve as a retrieval cue for *grape* (page 195), we defined *retrieval cues* as words or other stimuli that help us remember information stored in our memory. As we now consider these cues in more detail, we will see that they can be provided by a number of different sources.

An experience I had as I was preparing to leave home to go to class illustrates how *location* can serve as a retrieval cue. While I was in my office at home, I made a mental note to be sure to take the DVD on amnesia to school for my cognitive psychology class. A short while later, as I was leaving the house, I had a nagging feeling that I was forgetting something, but I couldn't remember what it was. This wasn't the first time I'd had this problem, so I knew exactly what to do. I returned to my office, and as soon as I got there I remembered that I was supposed to take the DVD. Returning to the place where I had originally thought about taking the disk helped me to retrieve my original thought. My office was a retrieval cue for remembering what I wanted to take to class.

You may have had similar experiences in which returning to a particular place stimulated memories associated with that place. The following description by one of my students illustrates retrieval of memories of childhood experiences:

> When I was 8 years old, both of my grandparents passed away. Their house was sold, and that chapter of my life was closed. Since then I can remember general things about being there as a child, but not the details. One day I decided to go for a drive. I went to my grandparents' old house and I pulled around to the alley and parked. As I sat there and stared at the house, the most amazing thing happened. I experienced a vivid recollection. All of a sudden, I was 8 years old again. I could see myself in the backyard, learning to ride a bike for the first time. I could see the inside of the house. I remembered exactly what every detail looked like. I could even remember the distinct smell. So many times I tried to remember these things, but never so vividly did I remember such detail. (Angela Paidousis)

My experience in my office and Angela's experience outside her grandparents' house are examples of retrieval cues that are provided by returning to the location where memories were initially formed. Many other things besides location can provide retrieval cues. Hearing a particular song can bring back memories for events you might not have thought about for years. Or consider smell. I once experienced a musty smell like the stairwell of my grandparents' house and was instantly transported back many decades to the experience of climbing those stairs as a child. The operation of retrieval cues has also been demonstrated in the laboratory using a technique called *cued recall*.

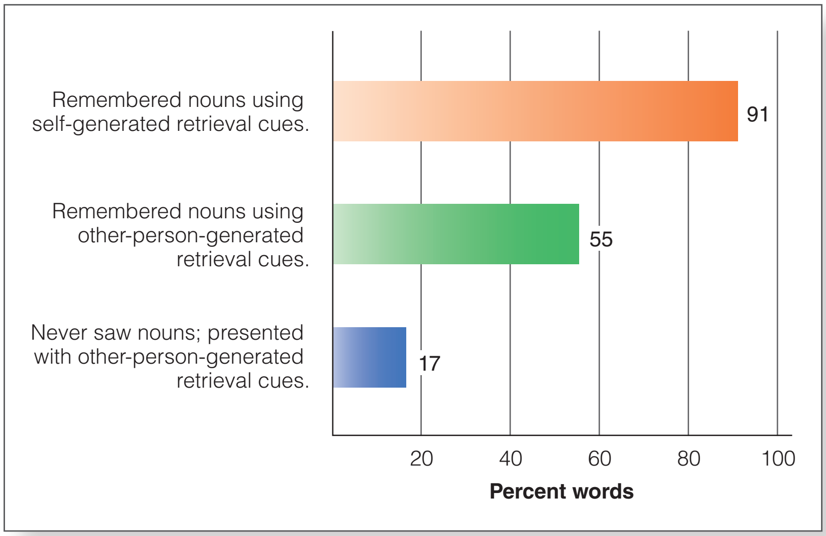
METHOD Cued Recall

We can distinguish two types of recall procedures. In **free recall**, a participant is simply asked to recall stimuli. These stimuli could be words previously presented by the experimenter or events experienced earlier in the participant's life. We have seen how this has been used in many experiments, such as the serial position curve experiment (page 164). In **cued recall**, the participant is presented with retrieval cues to aid in recall of the previously experienced stimuli. These cues are typically words or phrases. For example, Endel Tulving and Zena Pearlstone (1966) did an experiment in which they presented participants with a list of words to remember. The words were drawn from specific categories such as birds (*pigeon, sparrow*), furniture (*chair, dresser*), and professions (*engineer, lawyer*), although the categories were not specifically indicated in the original list. For the memory test, participants in the free recall group were asked to write down as many words as they could. Participants in the cued recall group were also asked to recall the words but were provided with the names of the categories, such as "birds," "furniture," and "professions."

The results of Tulving and Pearlstone's experiment demonstrate that retrieval cues aid memory. Participants in the free recall group recalled 40 percent of the words, whereas participants in the cued recall group who had been provided with the names of categories recalled 75 percent of the words.

One of the most impressive demonstrations of the power of retrieval cues was provided by Timo Mantyla (1986), who presented his participants with a list of 504 nouns, such as *banana, freedom*, and *tree*. During this study phase, participants were told to write three words they associated with each noun. For example, three words for *banana* might be *yellow, bunches*, and *edible*. In the test phase of the experiment, these participants were presented with the three words they had generated (self-generated retrieval cues) for half the nouns, or with three words that someone else had generated (other-person-generated retrieval cues) for the other half of the nouns. Their task was to remember the noun they had seen during the study phase.

The results indicated that when the self-generated retrieval cues were presented, participants remembered 91 percent of the words (top bar in **Figure 7.7**), but when the



➤ **Figure 7.7** Results of Mantyla's (1986) experiment. Memory was best when retrieval cues were created by the participant (top bar), and not as good when retrieval cues were created by someone else (middle bar). Control participants who tried to guess the words based on retrieval cues generated by someone else did poorly (bottom bar).

other-person-generated retrieval cues were presented, participants remembered only 55 percent of the words (second bar in Figure 7.7).

You might think it would be possible to guess *banana* from three properties like *yellow, bunches*, and *edible*, even if you had never been presented with the word *banana*. But when Mantyla ran another control group in which he presented the cue words generated by someone else to participants who had never seen the 504 nouns, these participants were able to determine only 17 percent of the nouns. The results of this experiment demonstrate that retrieval cues (the three words) provide extremely effective information for retrieving memories, but that *retrieval cues are significantly more effective when they are created by the person whose memory is being tested*. (Also see Wagenaar, 1986, which describes a study in which Wagenaar was able to remember almost all of 2,400 diary entries he kept over a 6-year period by using retrieval cues.)

Matching Conditions of Encoding and Retrieval

The retrieval cues in the two experiments we just described were verbal "hints"—category names like "furniture" in the Tulving and Pearlstone experiment and three-word descriptions created by the participants in the Mantyla experiment. But we have also seen another kind of "hint" that can help with retrieval: returning to a specific location, such as Angela's grandparents' house or my office.

Let's consider what happened in the office example, in which I needed to return to my office to retrieve my thought about taking a DVD to class. The key to remembering the DVD was that I retrieved the thought "Bring the DVD" by returning to the place where I had originally encoded that thought. This example illustrates the following basic principle: *Retrieval can be increased by matching the conditions at retrieval to the conditions that existed at encoding.*

We will now describe three specific situations in which retrieval is increased by matching conditions at retrieval to conditions at encoding. These different ways to achieve matching are (1) encoding specificity—matching the *context* in which encoding and retrieval occur; (2) state-dependent learning—matching the *internal mood* present during encoding and retrieval; and (3) transfer-appropriate processing—matching the *task* involved in encoding and retrieval.

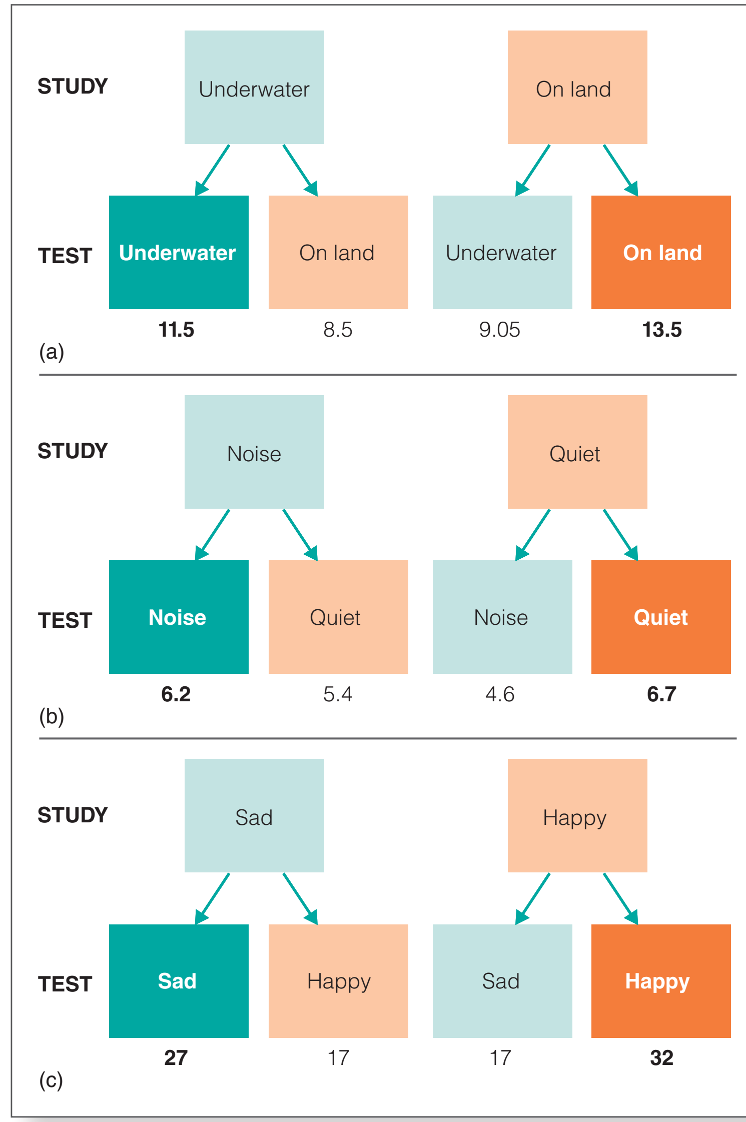
Encoding Specificity The principle of **encoding specificity** states that we encode information along with its context. For example, Angela encoded many experiences within the context of her grandparents' house. When she reinstated this context by returning to the house many years later, she remembered many of these experiences.

A classic experiment that demonstrates encoding specificity is D. R. Godden and Alan Baddeley's (1975) "diving experiment." In this experiment, one group of participants put on diving equipment and studied a list of words underwater, and another group studied the words on land (**Figure 7.8a**). These groups were then divided so that half the participants in the land and water groups were tested for recall on land and half were tested underwater. The results, indicated by the numbers, show that the best recall occurred when encoding and retrieval occurred in the same location.

The results of the diving study, and many others, suggest that a good strategy for test taking would be to study in an environment similar to the environment in which you will be tested. Although this doesn't mean you necessarily have to do all of your studying in the classroom where you will be taking the exam, you might want to duplicate in your study situation some of the conditions that will exist during the exam.

This conclusion about studying is supported by an experiment by Harry Grant and coworkers (1998), using the design in **Figure 7.8b**. Participants read an article on psychoimmunology while wearing headphones. The participants in the "quiet" condition heard nothing in the headphones. Participants in the "noise" condition heard a tape of background noise recorded during lunchtime in a university cafeteria (which they were told to ignore). Half the participants in each group were then given a short-answer test on the article under the quiet condition, and the other half were tested under the noise condition.

The results, shown in Figure 7.8b, indicate that participants did better when the testing condition matched the study condition. Because your next cognitive psychology exam will take place under quiet conditions, it might make sense to study under quiet conditions. (Interestingly, a number of my students report that having outside stimulation such as music or television present helps them study. This idea clearly violates the principle of encoding specificity. Can you think of some reasons that students might nonetheless say this?)



➤ **Figure 7.8** Design and results for (a) Godden and Baddeley's (1975) "diving" experiment; (b) Grant et al.'s (1998) "studying" experiment; (c) Eich and Metcalfe's (1989) "mood" experiment. Results for each test condition are indicated by the number directly under that condition. The matching colors (light green to dark green, and light orange to dark orange) indicate situations in which study and test conditions matched.

State-Dependent Learning Another example of how matching the conditions at encoding and retrieval can influence memory is **state-dependent learning**—learning that is associated with a particular *internal state*, such as mood or state of awareness. According to the principle of state-dependent learning, memory will be better when a person's internal state (mood or awareness) during retrieval matches his or her internal state during encoding. For example, Eric Eich and Janet Metcalfe (1989) demonstrated that memory is better when a person's mood during retrieval matches his or her mood during encoding. They did this by asking participants to think positive thoughts while listening to "merry" or happy music, or depressing thoughts while listening to "melancholic" or sad music (**Figure 7.8c**). Participants rated their mood while listening to the music, and the encoding part of the experiment began when their rating reached "very pleasant" or "very unpleasant." Once this occurred, usually within 15 to 20 minutes, participants studied lists of words while in their positive or negative mood.

After the study session ended, the participants were told to return in 2 days (although those in the sad group stayed in the lab a little longer, snacking on cookies and chatting with the experimenter while happy music played in the background, so they wouldn't leave the laboratory in a bad mood). Two days later, the participants returned, and the same procedure was used to put them in a positive or negative mood. When they reached the mood, they were given a memory test for the words they had studied 2 days earlier. The results, shown in Figure 7.8c, indicate that they did better when their mood at retrieval matched their mood during encoding (also see Eich, 1995).

The two ways of matching encoding and retrieval that we have described so far have involved matching the physical situation (encoding specificity) or an internal feeling (state-dependent learning). Our next example involves matching the type of *cognitive task* at encoding and retrieval.

Matching the Cognitive Task: Transfer-Appropriate Processing Donald Morris and coworkers (1977) did an experiment that showed that retrieval is better if *the same cognitive tasks are involved during both encoding and retrieval.* The procedure for their experiment was as follows:

Part I. Encoding

Participants heard a sentence with one word replaced by "blank," and 2 seconds later they heard a target word. There were two encoding conditions. In the *meaning condition*, the task was to answer "yes" or "no" based on the *meaning* of the word when it filled in the blank. In the *rhyming condition*, participants answered "yes" or "no" based on the *sound* of the word. Here are some examples:

Meaning Condition

1. Sentence: The *blank* had a silver engine.
   Target word: *train* Correct answer: "yes"
2. Sentence: The *blank* walked down the street.
   Target word: *building* Correct answer: "no"

Rhyming Condition

1. Sentence: *Blank* rhymes with pain.
   Target word: *Train* Correct answer: "yes"
2. Sentence: *Blank* rhymes with car.
   Target word: *Building* Correct answer: "no"

The important thing about these two groups of participants is that they were asked to *process* the words differently. In one case, they had to focus on the word's meaning to answer the question, and in the other case they focused on the word's sound.

Part II. Retrieval

The question Morris was interested in was how the participants' ability to retrieve the target words would be affected by the way they had processed the words during the encoding part of the experiment. There were a number of different conditions in this part of the experiment, but we are going to focus on what happened when participants were required to process words in terms of their sounds.

Participants in both the meaning group and the rhyming group were presented with a series of test words, one by one. Some of the test words rhymed with target words presented during encoding; some did not. Their task was to answer "yes" if the test word rhymed with one of the target words and "no" if it didn't. In the examples below, notice that the test words were always different from the target word.

Test word: *rain*	Answer:	"yes" (because it rhymes with the previously presented target word *train*)
Test word: *street*	Answer:	"no" (because it doesn't rhyme with any of the target words that were presented during encoding)

The key result of this experiment was that the participants' retrieval performance depended on whether the retrieval task matched the encoding task. As shown in

Figure 7.9, participants who had focused on rhyming during encoding remembered more words in the rhyming test than participants who had focused on meaning. Thus, participants who had focused on the word's *sound* during the first part of the experiment did better when the test involved focusing on sound. This result—better performance when the *type of processing* matches in encoding and retrieval—is called **transfer-appropriate processing**.

Transfer-appropriate processing is like encoding specificity and state-dependent learning because it demonstrates that matching conditions during encoding and retrieval improves performance. But, in addition, the result of this experiment has important implications for the levels of processing theory discussed earlier. Remember that the main idea behind levels of processing theory is that deeper processing leads to better encoding and, therefore, better retrieval. Levels of processing theory would predict that participants who were in the meaning group during encoding would experience "deeper" processing, so they should perform better. Instead, the rhyming group performed better. Thus, in addition to showing that matching the tasks at encoding and retrieval is important, Morris's experiment shows that deeper processing at encoding does not always result in better retrieval, as proposed by levels of processing theory.

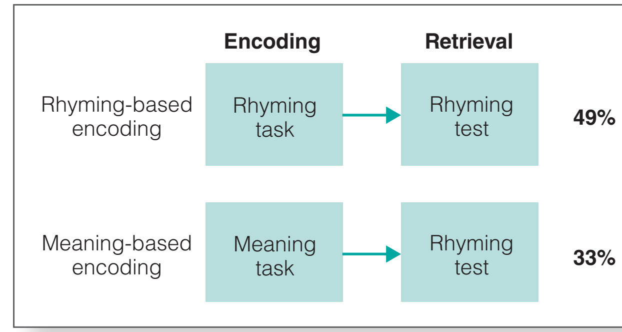


Figure 7.9 Design and results for the Morris et al. (1977) experiment. Participants who did a rhyming-based encoding task did better on the rhyming test than participants who did a meaning-based encoding task. This result would not be predicted by levels of processing theory but is predicted by the principle that better retrieval occurs if the encoding and retrieval tasks are matched.

Our approach to encoding and retrieval has so far focused on behavioral experiments that consider how conditions of encoding and retrieval affect memory. But there is another approach to studying encoding and retrieval that focuses on physiology. In the rest of this chapter, we will look "under the hood" of memory to consider how physiological changes that occur during encoding influence our ability to retrieve memory for an experience later.

TEST YOURSELF 7.2

1. Describe the following five ways of improving the effectiveness of studying: (1) elaborate; (2) generate and test; (3) organize; (4) take breaks; (5) avoid "illusions of learning." How does each technique relate to findings about encoding and retrieval?
2. What does it mean to be an "active" learner? How is this question related to the difference between taking notes by hand versus note taking on a laptop?
3. Retrieval cues are a powerful way to improve the chances that we will remember something. Why can we say that memory performance is better when you use a word in a sentence, create an image, or relate it to yourself, which are all techniques involving retrieval cues?
4. What is cued recall? Compare it to free recall.
5. Describe the Tulving and Pearlstone cued recall experiment and Mantyla's experiment in which he presented 600 words to his participants. What was the procedure and what was the result for each experiment, and what does each tell us about retrieval?
6. What is encoding specificity? Describe Baddeley and Godden's "diving" experiment and Grant's studying experiment. What does each one illustrate about encoding specificity? About cued recall?
7. What is state-dependent learning? Describe Eich and Metcalf's experiment about mood and memory.
8. Describe Morris's transfer-appropriate processing experiment. What aspect of encoding and retrieval was Morris studying? What implications do the results of this experiment have for matching encoding and retrieval? For levels of processing theory?

Consolidation: Establishing Memories

Memories have a history. Right after an event or learning has occurred, we remember many details of what happened or what we have learned. But with the passage of time and the accumulation of additional experiences, some of these memories are lost, some change their character, and some might end up being different than what actually happened.

Another observation about memory is that while every experience creates the potential for a new memory, new memories are fragile and can therefore be disrupted. This was first demonstrated experimentally by German psychologists Georg Müller and Alfons Pilzecker (1900; also see Dewar et al., 2007), who did an experiment in which two groups of participants learned lists of nonsense syllables. The "immediate" group learned one list and then immediately learned a second list. The "delay" group learned the first list and then waited for 6 minutes before learning the second list (**Figure 7.10**). When recall for the first list was measured, participants in the delay group remembered 48 percent of the syllables, but participants in the immediate (no delay) group remembered only 28 percent. Apparently, immediately presenting the second list to the "no delay" group interrupted the forming of a stable memory for the first list. Based on this result, Müller and Pilzecker proposed the term **consolidation**, which is defined as *the process that transforms new memories from a fragile state, in which they can be disrupted, to a more permanent state, in which they are resistant to disruption*.

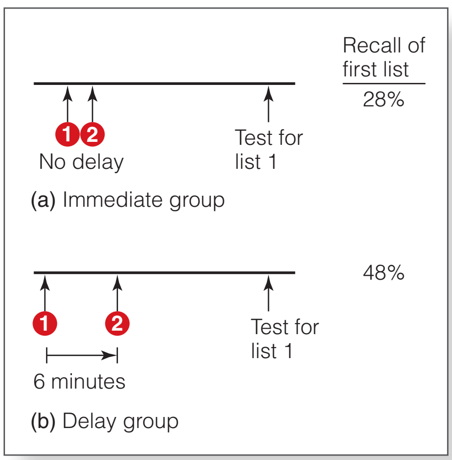


Figure 7.10 Procedure for Müller and Pilzecker's experiment. (a) In the immediate (no delay) condition, participants used the first list (1) and then immediately learned the second list (2). (b) In the delay condition, the second list was learned after a 6-minute delay. Numbers on the right indicate the percentage of items from the first list recalled when memory for that list was tested later.

In the more than 100 years since Müller and Pilzecker's pioneering experiment, researchers have discovered a great deal about the mechanisms responsible for consolidation and have distinguished two types, based on mechanisms that involve both synapses and neural circuits. Remember from Chapter 2 that synapses are the small spaces between the end of one neuron and the cell body or dendrite of another neuron (see Figure 2.4, page 29), and that when signals reach the end of a neuron, they cause neurotransmitters to be released onto the next neuron. Neural circuits are interconnected groups of neurons. **Synaptic consolidation**, which takes place over minutes or hours, involves structural changes at synapses. **Systems consolidation**, which takes place over months or even years, involves the gradual reorganization of neural circuits within the brain (Nader & Einarsson, 2010).

The fact that synaptic consolidation is relatively fast and systems consolidation is slower doesn't mean that we should think of them as two stages of a process that occur one after the other, like short-term memory and long-term memory in the modal model of memory (Figure 5.2, page 132). It is more accurate to think of them as occurring together, as shown in **Figure 7.11**, but at different speeds and at different levels of the nervous system. When something happens, a process is triggered that causes changes at the synapse. Meanwhile, a longer-term process begins that involves reorganization of neural circuits. Thus, synaptic and systems consolidation are processes that occur simultaneously—one that works rapidly, at the level of the synapse, and another that works more slowly, at the level of neural circuits.

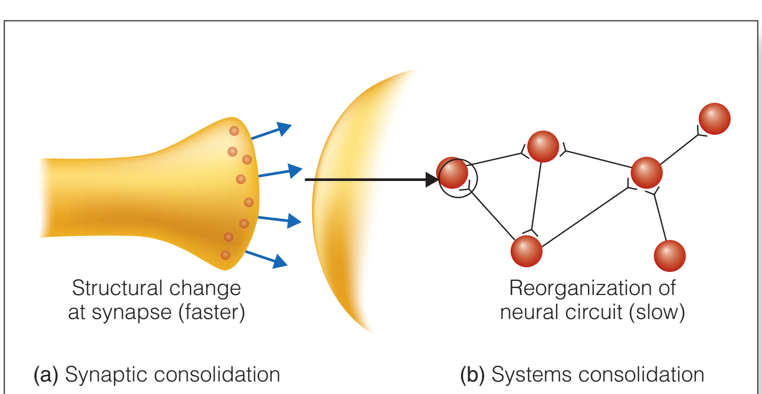


Figure 7.11 Synaptic and systems consolidation. (a) Synaptic consolidation involves changes at the synapses. (a) Systems consolidation involves reorganization of neural connections and takes place over a longer time span.

Synaptic Consolidation: Experience Causes Changes at the Synapse

According to an idea first proposed by the Canadian psychologist Donald Hebb (1948), learning and memory are represented in the brain by physiological changes that

SOME QUESTIONS WE WILL CONSIDER

- What kinds of events from our lives are we most likely to remember? (228)
- Is there something special about memory for extraordinary events like the 9/11 terrorist attacks? (232)
- What properties of the memory system make it both highly functional and also prone to error? (236)
- Why is eyewitness testimony often cited as the cause of wrongful convictions? (248)
- Why would someone confess to a crime they didn't commit? (254)

What? Another chapter on memory? Yes, another chapter, because there's still more to explain, especially about how memory operates in everyday life. But before embarking on this final chapter on memory, let's look back at how we got here and what remains to be explained.

The Journey So Far

We began our investigation of memory in Chapter 5 by asking what memory is and what it does, and by describing Atkinson and Shiffrin's information-processing model of memory, which proposed three types of memory (sensory, short-term, and long-term) (Figure 5.2). Although primitive compared to present-day concepts of memory, this model captured the idea that memory is a process that unfolds in steps. This was important not only because it began identifying what happens to information on its way to either becoming a memory or being forgotten, but also because it provided a way to focus on different stages of the process of memory.

The original three-stage model of memory led to the idea that memory is a dynamic process involving not just storage, but also the manipulation of information. Picturing memory as a dynamic information-processing system provided a good entry point for the realization, described in Chapter 6, that remembering the trip you took last summer and that Lady Gaga is a well-known singer who wears outrageous costumes are served by different systems—episodic memory and semantic memory, respectively, which operate separately but which also interact. By the end of Chapter 6, you probably realized that cognition—and certainly memory—is all about interconnectedness between structures and processes.

But after describing how memory deals with different types of information, another question remained: What *processes* are involved in (a) transferring incoming information into memory and (b) retrieving that information when we want to remember it? As we considered these questions in Chapter 7, we described neural mechanisms responsible for the process of consolidation, which strengthens memories, making them more permanent.

But as sometimes happens when you're telling a story, there's a twist to what appears to be a predictable plot, and the rat experiment described at the end of Chapter 7 showed that memories that were originally thought to be firmly consolidated can become fragile and changeable. And just to make this plot twist more interesting, it turns out that when established memories are remembered, they undergo a process called *reconsolidation*, during which they can be changed.

But some people might be tempted to say, in response to this description of once-solid memories becoming fragile, that the laboratory-based research on rats on which this finding is based may not translate to real-life memories in humans. After all, they might say, our experience teaches us that we often remember things accurately. This idea that memories are generally accurate is consistent with the finding of a nationwide poll in which 63 percent of people agreed with the statement "Human memory works like a video camera, accurately recording the events we see and hear so we can review and interpret them later." In the same survey, 48 percent agreed that "once you have experienced an event and formed a memory of it, that memory does not change" (Simons & Chabris, 2011). Thus, a substantial proportion of people believe memories are recorded accurately, as if by a video camera, and that once recorded, the memory does not change.

As we will see in this chapter, these views are erroneous. Everything that happens is not necessarily recorded accurately in the first place, and even if it is, there is a good chance that what you remember may not accurately reflect what actually happened.

But the most important thing about this chapter is not just that it demonstrates limits to our ability to remember, but that it illustrates a basic property of memory: Memories are created by a process of construction, in which what actually happened, other things that happened later, and our general knowledge about how things usually happen are combined to create our memory of an event.

We will illustrate this process of construction by shifting our focus from experiments in which participants are asked to remember lists of words or short passages to experiments in which participants are asked to remember events that have occurred in their lives.

Autobiographical Memory: What Has Happened in My Life

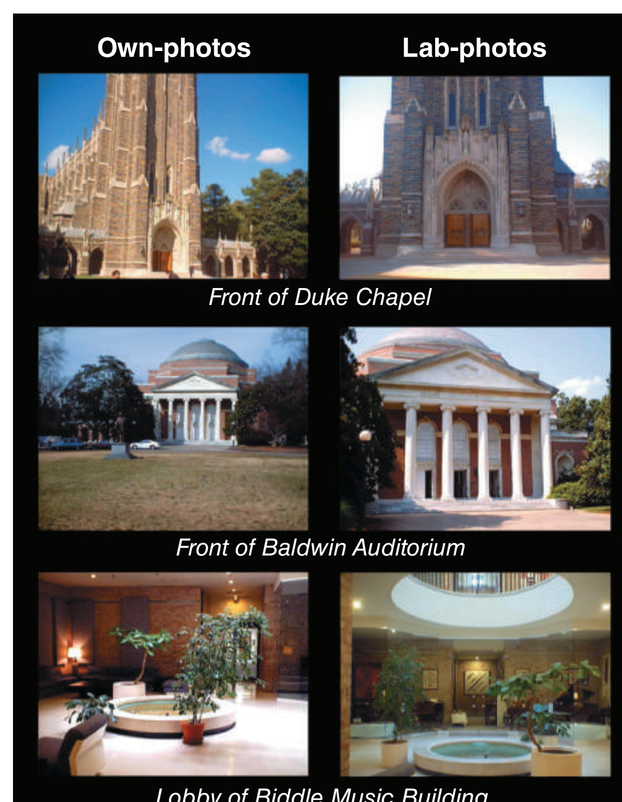
Autobiographical memory is memory for specific experiences from our life, which can include both episodic and semantic components (see Chapter 6, page 172). For example, an autobiographical memory of a childhood birthday party might include images of the cake, people at the party, and games being played (episodic memory); it might also include knowledge about when the party occurred, where your family was living at the time, and your general knowledge about what usually happens at birthday parties (semantic memory) (Cabeza & St. Jacques, 2007). Two important characteristics of autobiographical memories are (1) they are multidimensional and (2) we remember some events in our lives better than others.

The Multidimensional Nature of Autobiographical Memory

Think about a memorable moment in your life—an event involving other people or a solitary memorable experience. Whatever experience you remember, it is pretty certain that there are many components to your memory: visual—what you see when you transport yourself back in time; auditory—what people are saying or other sounds in the environment; and perhaps smells, tastes, and tactile perceptions as well. But memories extend beyond vision, hearing, touch, taste, and smell. They also have spatial components, because events usually take place in a three-dimensional environment. And perhaps most important of all, memories often involve thoughts and emotions, both positive and negative.

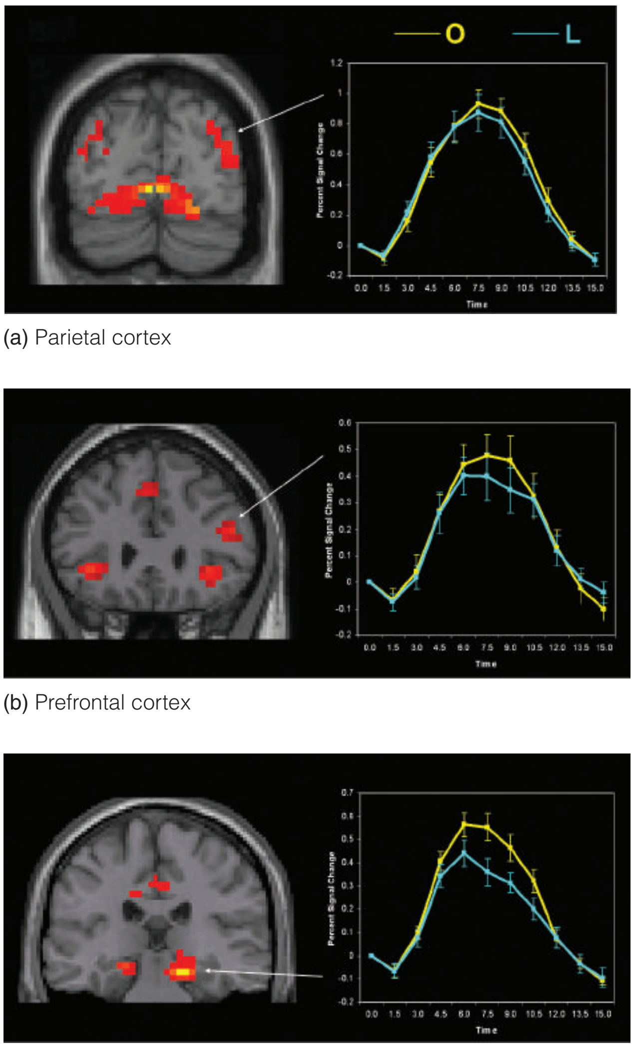
All this is a way of saying that memories are multidimensional, with each dimension playing its own, often important, role in the memory. The importance of individual components is illustrated by the finding that patients who have lost their ability to recognize or visualize objects, because of damage to the visual area of their cortex, can experience a loss of autobiographical memory (Greenberg & Rubin, 2003). This may have occurred because visual stimuli were not available to serve as retrieval cues for memories. But even memories not based on visual information are lost in these patients. Apparently, visual experience plays an important role in autobiographical memory. (It would seem reasonable that for blind people, auditory experience might take over this role.)

A brain-scanning study that illustrates a difference between autobiographical memory and laboratory memory was done by Roberto Cabeza and coworkers (2004). Cabeza measured the brain activation caused by two sets of stimulus photographs—one set that the participant took and another set that was taken by someone else (**Figure 8.1**). We will call the photos taken by the participant own-photos, and the ones taken by someone else lab-photos.



R.Cabeza,S.E.Prince, S.M. Daselaar, D.L. Greenber, M. Budde,F. Dolcos,et al., Brain activity during episodic retrieval of autobiographical and laboratory events: An fMRI study using novel photo paradigm. Journal of Cognitive Neuroscience, 16, 1583-1594, 2004.

Figure 8.1 Photographs from Cabeza and coworkers' (2004) experiment. Own-photos were taken by the participant; lab-photos were taken by someone else. (Source: Cabeza et al., 2004)



(a) Parietal cortex

(b) Prefrontal cortex

(c) Hippocampus

Own-photos = more activation

➤ **Figure 8.2** (a) fMRI response of an area in the parietal cortex showing time-course and amplitude of response caused by own-photos (yellow) and lab-photos (blue) in the memory test. The graph on the right indicates that activation is the same with the own-photos and lab-photos. The response to own-photos is larger in (b) the prefrontal cortex and (c) the hippocampus. (Source: Cabeza et al., 2004)

The photos were created by giving 12 Duke University students digital cameras and telling them to take pictures of 40 specified campus locations over a 10-day period. After taking the photos, participants were shown their own-photos and a lab-photo of each location. A few days later they saw the own-photos and the lab-photos they had seen before, along with some new lab-photos they had never seen. As participants indicated whether each stimulus was an own-photo, a lab-photo they had seen before, or a new lab-photo, their brain activity was measured in an fMRI scanner.

The brain scans showed that own-photos and lab-photos activated many of the same structures in the brain—mainly ones like the medial temporal lobe (MTL) that are associated with episodic memory, as well as an area in the parietal cortex involved in processing scenes (**Figure 8.2a**). But in addition, the own-photos caused more activation in the prefrontal cortex, which is associated with processing information about the self (**Figure 8.2b**), and in the hippocampus, which is involved in recollection (memory associated with "mental time travel") (**Figure 8.2c**).

Thus, the pictures of a particular location that people took themselves elicited memories presumably associated with taking the picture and, therefore, activated a more extensive network of brain areas than pictures of the same location that were taken by someone else. This activation reflects the richness of experiencing autobiographical memories. Other studies have also found that autobiographical memories can elicit emotions, which activates another area of the brain (which we will describe shortly) called the amygdala (see Figure 5.19, page 150).

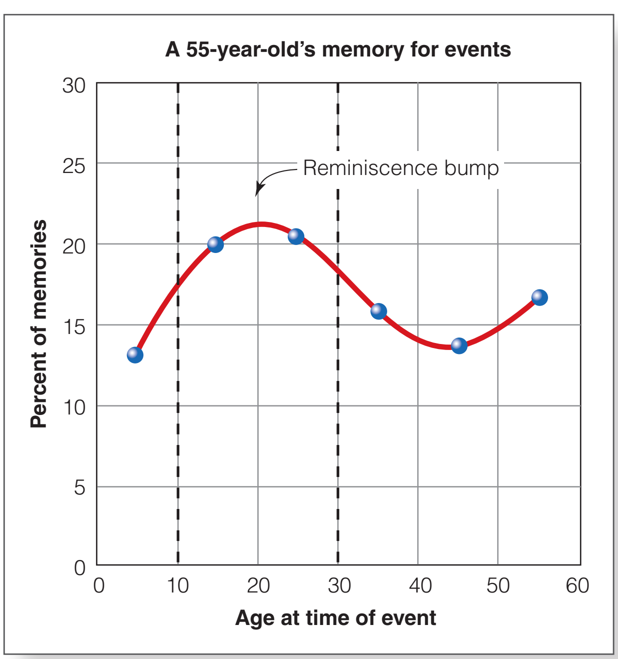
Memory Over the Life Span

What determines which particular life events we will remember years later? Personal milestones such as graduating from college or receiving a marriage proposal stand out, as do highly emotional events such as surviving a car accident (Pillemer, 1998). Events that become significant parts of a person's life tend to be remembered well. For example, going out to dinner with someone for the first time might stand out if you ended up having a long-term relationship with that person, but the same dinner date might be far less memorable if you never saw the person again.

A particularly interesting result occurs when participants over 40 are asked to remember events in their lives. As shown in **Figure 8.3** for a 55-year-old, events are remembered for all years between ages 5 and 55, but memory is better for recent events and for events occurring between the ages of about 10 and 30 (Conway, 1996; Rubin et al., 1998). The enhanced memory for adolescence and young adulthood found in people over 40 is called the **reminiscence bump**.

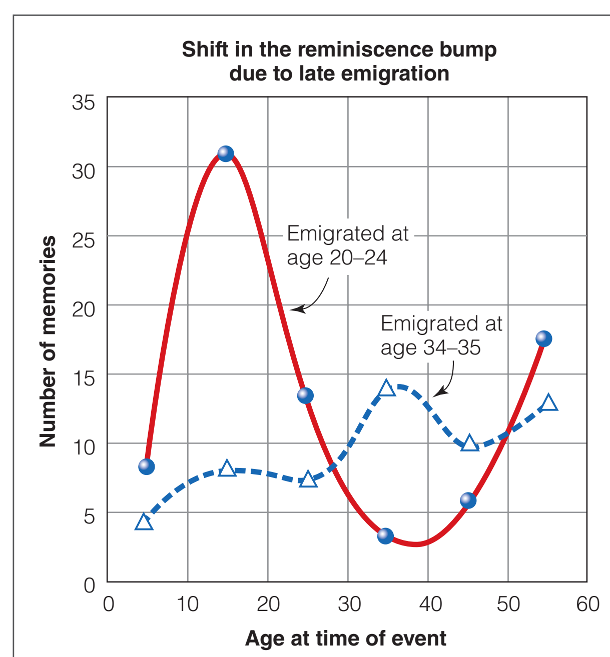
Why are adolescence and young adulthood special times for encoding memories? We will describe three hypotheses, all based on the idea that special life events happen during adolescence and young adulthood. The **self-image hypothesis** proposes that memory is enhanced for events that occur as a person's self-image or life identity is being formed (Rathbone et al., 2008). This idea is based on the results of an experiment in which participants with an average age of 54 created "I am" statements, such as "I am a mother" or "I am a psychologist," that they felt defined them as a person. When they then indicated when each statement had become a significant part of their identity, the average age they assigned to the origin of these statements was 25, which is within the span of the reminiscence bump. When participants also listed events that were connected with each statement (such as "I gave birth to my first child" or "I started graduate school in psychology"), most of the events occurred during the time span associated with the reminiscence bump. Development of the self-image therefore brings with it numerous memorable events, most of which happen during adolescence or young adulthood.

Another explanation for the reminiscence bump, called the **cognitive hypothesis**, proposes that periods of rapid change that are followed by stability cause stronger encoding of memories. Adolescence and young adulthood fit this description because the rapid changes, such as going away to school, getting married, and starting a career, that occur during these periods are followed by the relative stability of adult life. One way this hypothesis has been tested is by finding people who have experienced rapid changes in their lives that occurred at a time later than adolescence or young adulthood. The cognitive hypothesis would predict that the reminiscence bump should occur later for these people. To test this idea, Robert Schrauf and David Rubin (1998) determined the recollections of people who had emigrated to the United States either in their 20s or in their mid-30s. **Figure 8.4**, which shows the memory curves for two groups of immigrants, indicates that the reminiscence



➤ **Figure 8.3** Percentage of memories from different ages recalled by a 55-year-old, showing the reminiscence bump, which occurs for events experienced between about 10 and 30 years of age (dashed lines).

(Source: R. W. Schrauf & D. C. Rubin, Bilingual autobiographical memory in older adult immigrants: A test of cognitive explanations of the reminiscence bump and the linguistic encoding of memories, *Journal of Memory and Language*, 39, 437–457. Copyright © 1998 Elsevier Ltd. Republished with permission.)



➤ **Figure 8.4** The reminiscence bump for people who emigrated at age 34 or 35 is shifted toward older ages, compared to the bump for people who emigrated between the ages of 20 and 24.

(Source: R. W. Schrauf & D. C. Rubin, Bilingual autobiographical memory in older adult immigrants: A test of cognitive explanations of the reminiscence bump and the linguistic encoding of memories, *Journal of Memory and Language*, 39, 437–457. Copyright © 1998 Elsevier Ltd. Republished with permission.)

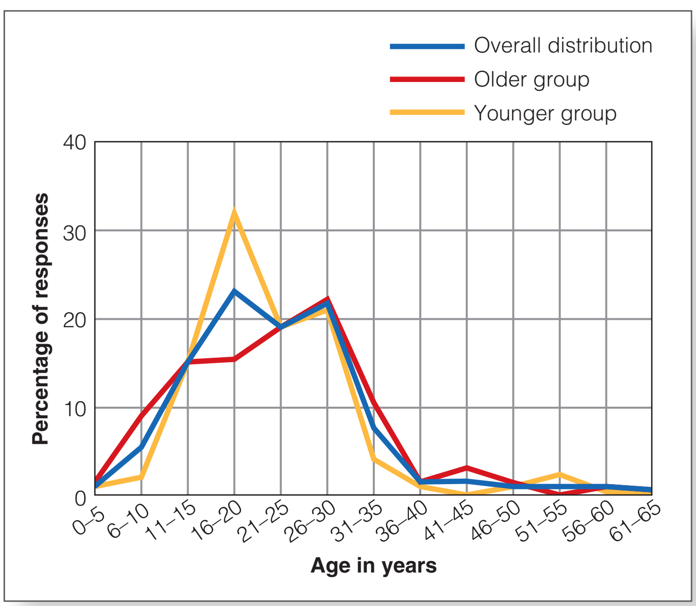
bump occurs at the normal age for people who emigrated at age 20 to 24 but is shifted to later for those who emigrated at age 34 or 35, just as the cognitive hypothesis would predict.

Notice that the normal reminiscence bump is missing for the people who emigrated later. Schrauf and Rubin explain this by noting that the late emigration eliminates the stable period that usually occurs during early adulthood. Because early adulthood isn't followed by a stable period, no reminiscence bump occurs, as predicted by the cognitive hypothesis.

Finally, the **cultural life script hypothesis** distinguishes between a person's life story, which is all of the events that have occurred in a person's life, and a **cultural life script**, which is the culturally expected events that occur at a particular time in the life span. For example, when Dorthe Berntsen and David Rubin (2004) asked people to list when important events in a typical person's life usually occur, some of the more common responses were falling in love (16 years), college (22 years), marriage (27 years), and having children (28 years). Interestingly, a large number of the most commonly mentioned events occur during the period associated with the reminiscence bump. This doesn't mean that events in a specific person's life always occur at those times, but according to the cultural life script hypothesis, events in a person's life story become easier to recall when they fit the cultural life script for that person's culture.

Related to the cultural life script hypothesis is a phenomenon Jonathan Koppel and Dorthe Berntsen (2014) call the **youth bias**—the tendency for the most notable public events in a person's life to be perceived to occur when the person is young. They reached this conclusion by asking people to imagine a typical infant of their own culture and gender, and by posing the following question: ". . . throughout this person's life many important public events will take place, both nationally and internationally, such as wars, the deaths of public figures, and sporting events. How old do you think this person is most likely to be when the event that they consider to be the *most* important public event of their lifetime takes place?"

As shown in **Figure 8.5**, most of the responses indicated that the person would perceive most important public events to occur before they were 30. Interestingly, this result occurred when polling both young and older people, and the curves peak in the teens and 20s, just like the reminiscence bump.



➤ **Figure 8.5** Results of Koppel and Berntsen's (2014) "youth bias" experiment in which participants were asked to indicate how old a hypothetical person would be when the event that they consider to be the most important public event of their lifetime takes place. Notice that the distribution of responses is similar for both younger participants and older participants.

(Source: Koppel and Berntsen, *Quarterly Journal of Experimental Psychology*, 67(3), Figure 1, page 420, 2014.)

The reminiscence bump is a good example of a phenomenon that has generated a number of explanations, many of them plausible and supported by evidence. It isn't surprising that the crucial factors proposed by each explanation—formation of self-identity, rapid changes followed by stability, and culturally expected events—all occur during the reminiscence bump, because that is what they are trying to explain. It is likely that each of the mechanisms we have described makes some contribution to creating the reminiscence bump. (See **Table 8.1**.)

TABLE 8.1

Explanations for the Reminiscence Bump

Explanation	Basic Characteristic
Self-image	Period of assuming person's self-image
Cognitive	Encoding is better during periods of rapid change
Cultural life script	Culturally shared expectations structure recall

Memory for "Exceptional" Events

It is clear that some events in a person's life are more likely to be remembered than others. A characteristic of most memorable events is that they are significant and important to the person and, in some cases, are associated with emotions. For example, think about some of the memorable things you remember from your first year in college. When upperclass students were asked to remember events from their first year of college, many of the events that stand out were associated with strong emotions (Pillemer, 1998; Pillemer et al., 1996; Talarico, 2009).

Memory and Emotion

Emotions and memory are intertwined. Emotions are often associated with "special" events, such as beginning or ending relationships or events experienced by many people simultaneously, like the 9/11 terrorist attacks. The idea that emotions are associated with better memory has some support. In one experiment on the association between emotion and enhanced memory, Kevin LaBar and Elizabeth Phelps (1998) tested participants' ability to recall arousing words (for example, profanity and sexually explicit words) and neutral words (such as *street* and *store*), and observed better memory for the arousing words (**Figure 8.6a**). In another study, Florin Dolcos and coworkers (2005) tested participants' ability to recognize emotional and neutral pictures after a 1-year delay and observed better memory for the emotional pictures (**Figure 8.6b**).

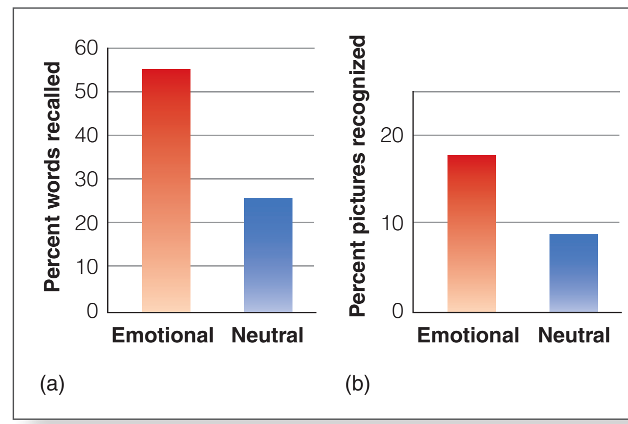


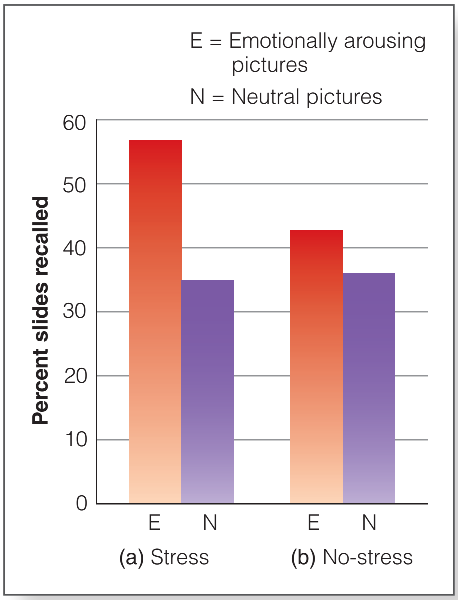
Figure 8.6 (a) Percent of emotional and neutral words recalled immediately after reading a list of words. (b) Percent of emotional and neutral pictures recognized 1 year after viewing the pictures.
(Source: Part a: LaBar & Phelps, 1998; Part b: Dolcos et al., 2005.)

When we look at what is happening physiologically, one structure stands out: the **amygdala** (see Figure 5.19, page 150). The importance of the amygdala has been demonstrated in a number of ways. For example, in the experiment by Dolcos and coworkers described above, brain scans using fMRI as people were remembering revealed that amygdala activity was higher for the emotional words (also see Cahill et al., 1996; Hamann et al., 1999).

The link between emotions and the amygdala was also demonstrated by testing a patient, B.P., who had suffered damage to his amygdala. When participants without brain damage viewed a slide show about a boy and his mother in which the boy is injured halfway through the story, these participants had enhanced memory for the emotional part of the story (when the boy is injured). B.P.'s memory was the same as that of the non-brain-damaged participants for the first part of the story, but it was not enhanced for the emotional part (Cahill et al., 1995). It appears, therefore, that emotions may trigger mechanisms in the amygdala that help us remember events associated with the emotions.

Emotion has also been linked to improved memory consolidation, the process that strengthens memory for an experience and takes place over minutes or hours after the experience (see Chapter 7, pages 208–215) (LaBar & Cabeza, 2006; Tambini et al., 2017). The link between emotion and consolidation was initially suggested by animal research, mainly in rats, that showed that central nervous system stimulants administered shortly after training on a task can enhance memory for the task. Research then determined that hormones such as the stimulant cortisol are released during and after emotionally arousing stimuli like those used in the testing task. These two findings led to the conclusion that stress hormones released after an emotional experience increase consolidation of memory for that experience (McGaugh, 1983; Roozendaal & McGaugh, 2011).

Larry Cahill and coworkers (2003) carried out an experiment that demonstrated this effect in humans. They showed participants neutral and emotionally arousing pictures; then



➤ **Figure 8.7** (a) Recall for emotional pictures is better than for neutral pictures when subjects are exposed to stress. (b) There is no significant difference between emotional and neutral recall in the no-stress condition. This result has been related to enhanced memory consolidation for the emotional pictures. (Source: Cahill et al., 2003)

they had some participants (the stress group) immerse their arms in ice water, which causes the release of cortisol, and other participants (the no-stress group) immerse their arms in warm water, which is a nonstressful situation that doesn't cause cortisol release. When asked to describe the pictures a week later, participants who had been exposed to stress recalled more of the emotionally arousing pictures than the neutral pictures (**Figure 8.7a**). There was no significant difference between the neutral and emotionally arousing picture for the no-stress group (**Figure 8.7b**).

What is particularly interesting about these results is that the cortisol enhances memory for the emotional pictures but not for the neutral pictures. Results such as these have led to the conclusion that hormone activation that occurs after arousing emotional experiences enhances memory consolidation in humans (also see Phelps & Sharot, 2008). This increased consolidation associated with emotion has also been linked to increased activity in the amygdala (Ritchey et al., 2008). As we will see in the next section, there is a link between emotion and memory for highly memorable events, such as the 9/11 terrorist attacks, which cause memories that have been called *flashbulb memories*.

Flashbulb Memories

Many people have memories of when they learned about the terrorist attacks of September 11, 2001. Research on memories for public events such as this, which have been experienced by large numbers of people, often ask people to remember where they were and how they first learned of the event. I remember walking into the psychology department office and having a secretary tell me that someone had crashed a plane into the World Trade Center. At the time, I pictured a small private plane that had gone off course, but a short while later, when I called my wife, she told me that the first tower of the World Trade Center had just collapsed. Shortly after that, in my cognitive psychology class, my students and I discussed what we knew about the situation and decided to cancel class for the day.

Brown and Kulik Propose the Term "Flashbulb Memory" The memories I have described about how I heard about the 9/11 attack, and the people and events directly associated with finding out about the attack, are still vivid in my mind more than 16 years later. Is there something special about memories such as this that are associated with unexpected, emotionally charged events? According to Roger Brown and James Kulik (1977), there is. They proposed that memories for the circumstances surrounding learning about events such as 9/11 are special. Their proposal was based on an earlier event, which occurred on November 22, 1963. President John F. Kennedy was sitting high up in an open-top car, waving to people as his motorcade drove down a parade route in Dallas, Texas. As his car was passing the Texas School Book Depository building, three shots rang out. President Kennedy slumped over. The motorcade came to a halt, and Kennedy was rushed to the hospital. Shortly after, the news spread around the world: President Kennedy had been assassinated.

In referring to the day of President Kennedy's assassination, Brown and Kulik stated that "for an instant, the entire nation and perhaps much of the world stopped still to have its picture taken." This description, which likened the process of forming a memory to the taking of a photograph, led them to coin the term **flashbulb memory** to refer to a person's memory for the circumstances surrounding shocking, highly charged events. It is important to emphasize that the term *flashbulb memory* refers to memory for the circumstances surrounding how a person *heard about* an event, not memory *for the event itself*. Thus, a flashbulb memory for 9/11 would be memory for where a person was and what they were doing when they found out about the terrorist attack. Therefore, flashbulb memories give importance to events that otherwise would be unexceptional. For example, although I had talked with the secretary in the psychology department hundreds of times over the years, the one time that stands out is when she told me that a plane had crashed into the World Trade Center.

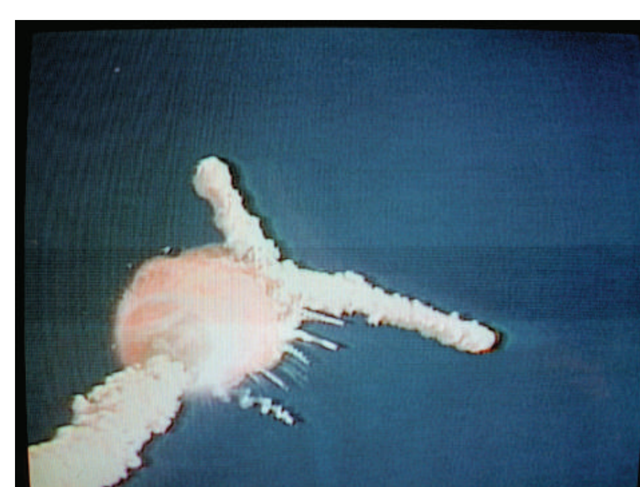
Brown and Kulik argued that there is something special about the mechanisms responsible for flashbulb memories. Not only do they occur under highly emotional circumstances, but they are remembered for long periods of time and are especially vivid and detailed. Brown and Kulik described the mechanism responsible for these vivid and detailed memories as a "Now Print" mechanism, as if these memories are like a photograph that resists fading.

Flashbulb Memories Are Not Like Photographs Brown and Kulik's idea that flashbulb memories are like a photograph was based on their finding that people were able to describe in some detail what they were doing when they heard about highly emotional events like the assassinations of John F. Kennedy and Martin Luther King, Jr. But the procedure Brown and Kulik used was flawed because their participants weren't asked what they remembered until years after the events had occurred. The problem with this procedure is that there was no way to determine whether the reported memories were accurate. The only way to check for accuracy is to compare the person's memory to what actually happened or to memory reports collected immediately after the event. The technique of comparing later memories to memories collected immediately after the event is called repeated recall.

METHOD Repeated Recall

The idea behind repeated recall is to determine whether memory changes over time by testing participants a number of times after an event. The person's memory is first measured immediately after a stimulus is presented or something happens. Even though there is some possibility for errors or omissions immediately after the event, this report is taken as being the most accurate representation of what happened and is used as a baseline. Days, months, or years later, when participants are asked to remember what happened, their reports are compared to this baseline. This use of a baseline provides a way to check the consistency of later reports.

Over the years since Brown and Kulik's "Now Print" proposal, research using the repeated recall task has shown that flashbulb memories are not like photographs. Unlike photographs, which remain the same for many years, people's memories for how they heard about flashbulb events change over time. In fact, one of the main findings of research on flashbulb memories is that although people report that memories surrounding flashbulb events are especially vivid, they are often inaccurate or lacking in detail. For example, Ulric Neisser and Nicole Harsch (1992) did a study in which they asked participants how they had heard about the explosion of the space shuttle *Challenger*. Back in 1986, space launches were still considered special and were often highly anticipated. The flight of the *Challenger* was special because one of the astronauts was New Hampshire high school teacher Christa McAuliffe, who was the first member of NASA's Teacher in Space project. The blastoff from Cape Canaveral on January 28, 1986, seemed routine. But 77 seconds after liftoff, Challenger broke apart and plummeted into the ocean, killing the crew of seven (**Figure 8.8**). Participants in Neisser and Harsch's experiment filled out a questionnaire within a day after the explosion, and then filled out the same questionnaire 2 1/2 to 3 years later. One participant's response, a day after the explosion, indicated that she had heard about it in class:



Bettmann/Getty Images

Figure 8.8 Neisser and Harsch (1992) studied people's memories for the day they heard about the explosion of the space shuttle *Challenger*.

> I was in my religion class and some people walked in and started talking about [it]. I didn't know any details except that it had exploded and the schoolteacher's students had all been

> watching, which I thought was so sad. Then after class I went to my room and watched the TV program talking about it, and I got all the details from that.

Two and a half years later, her memory had changed to the following:

> When I first heard about the explosion I was sitting in my freshman dorm room with my roommate, and we were watching TV. It came on a news flash, and we were both totally shocked. I was really upset, and I went upstairs to talk to a friend of mine, and then I called my parents.

Responses like these, in which participants first reported hearing about the explosion in one place, such as a classroom, and then later remembered that they had first heard about it on TV, were common. Right after the explosion, only 21 percent of the participants indicated that they had first heard about it on TV, but 2 1/2 years later, 45 percent of the participants reported that they had first heard about it on TV. Reasons for the increase in TV memories could be that the TV reports become more memorable through repetition and that TV is a major source of news. Thus, memory for hearing about the Challenger explosion had a property that is also a characteristic of memory for less dramatic, everyday events: It was affected by people's experiences following the event (people may have seen accounts of the explosion) and their general knowledge (people often first hear about important news on TV).

The idea that memory can be affected by what happens after an event is the basis of Ulric Neisser and coworkers (1996) **narrative rehearsal hypothesis**, which states that we may remember events like those that happened on 9/11 not because of a special mechanism but because we rehearse these events after they occur.

The narrative rehearsal hypothesis makes sense when we consider the events that followed 9/11. Pictures of the planes crashing into the World Trade Center were replayed endlessly on TV, and the event and its aftermath were covered extensively for months afterward in the media. Neisser argues that if rehearsal is the reason for our memories of significant events, then the flashbulb analogy is misleading.

Remember that the memory we are concerned with is the characteristics surrounding how people first heard about 9/11, but much of the rehearsal associated with this event is rehearsal for events that occurred after hearing about it. Seeing TV replays of the planes crashing into the towers, for example, might result in people focusing more on those images than on who told them about the event or where they were, and eventually they might come to believe that they originally heard about the event on TV, as occurred in the *Challenger* study.

An indication of the power of TV to "capture" people's memory is provided by the results of a study by James Ost and coworkers (2002), who approached people in an English shopping center and asked if they would be willing to participate in a study examining how well people can remember tragic events. The target event involved Princess Diana and her companion Dodi Fayed, whose deaths in a car crash in Paris on August 31, 1997, were widely covered on British television. Participants were asked to respond to the following statement: "Have you seen the paparazzi's video-recording of the car crash in which Diana, Princess of Wales, and Dodi Fayed lost their lives?" Of the 45 people who responded to this question, 20 said they had seen the film. This was, however, impossible, because no such film exists. The car crash was reported on TV, but not actually shown. The extensive media coverage of this event apparently caused some people to remember something—seeing the film—that didn't actually occur.

Are Flashbulb Memories Different from Other Memories? The large number of inaccurate responses in the *Challenger* study suggests that perhaps memories that are supposed to be flashbulb memories decay just like regular memories. In fact, many flashbulb memory researchers have expressed doubt that flashbulb memories are much different from regular memories (Schmolck et al., 2000). This conclusion is supported by an experiment in which a group of college students were asked a number of questions on September 12, 2001, the day after the terrorist attacks involving the World Trade Center, the Pentagon, and Flight 93 in Pennsylvania (Talarico & Rubin, 2003). Some of these questions were about the terrorist attacks ("When did you first hear the news?"). Others were similar questions about an everyday event in the person's life that occurred in the days just preceding the attacks. After picking the everyday event, the participant created a two- or three-word description that could serve as a cue for that event in the future. Some participants were retested 1 week later, some 6 weeks later, and some 32 weeks later by asking them the same questions about the attack and the everyday event.

One result of this experiment was that the participants remembered fewer details and made more errors at longer intervals after the events, with little difference between the results for the flashbulb and everyday memories (**Figure 8.9a**). Thus, details fade for flashbulb memories, just as they do for everyday memories. So why do people think flashbulb memories are special? The results shown in **Figure 8.9b** and **8.9c** may hold the answer. People's memories for flashbulb events remain *more vivid* than everyday memories (Figure 8.9b), and people *believe* that flashbulb memories remain accurate, while everyday memories don't (Figure 8.9c).

Thus, we can say that flashbulb memories are both special (vivid; likely to be remembered) and ordinary (may not be accurate) at the same time. Another way of noting the specialness of flashbulb memories is that people *do* remember them—even if inaccurately—whereas less noteworthy events are less likely to be remembered.

Memory researchers are still discussing the exact mechanism responsible for memory of flashbulb events (Berntsen, 2009; Luminet & Curci, 2009; Talarico & Rubin, 2009). However, whatever mechanism is involved, one important outcome of the flashbulb memory research is that it has revealed that what people believe they remember accurately may not, in fact, be accurate at all. The idea that people's memories for an event can be determined by factors in addition to actually experiencing the event has led many researchers to propose that what people remember is a "construction" that is based on what actually happened plus additional influences. We will discuss this idea in the next section.

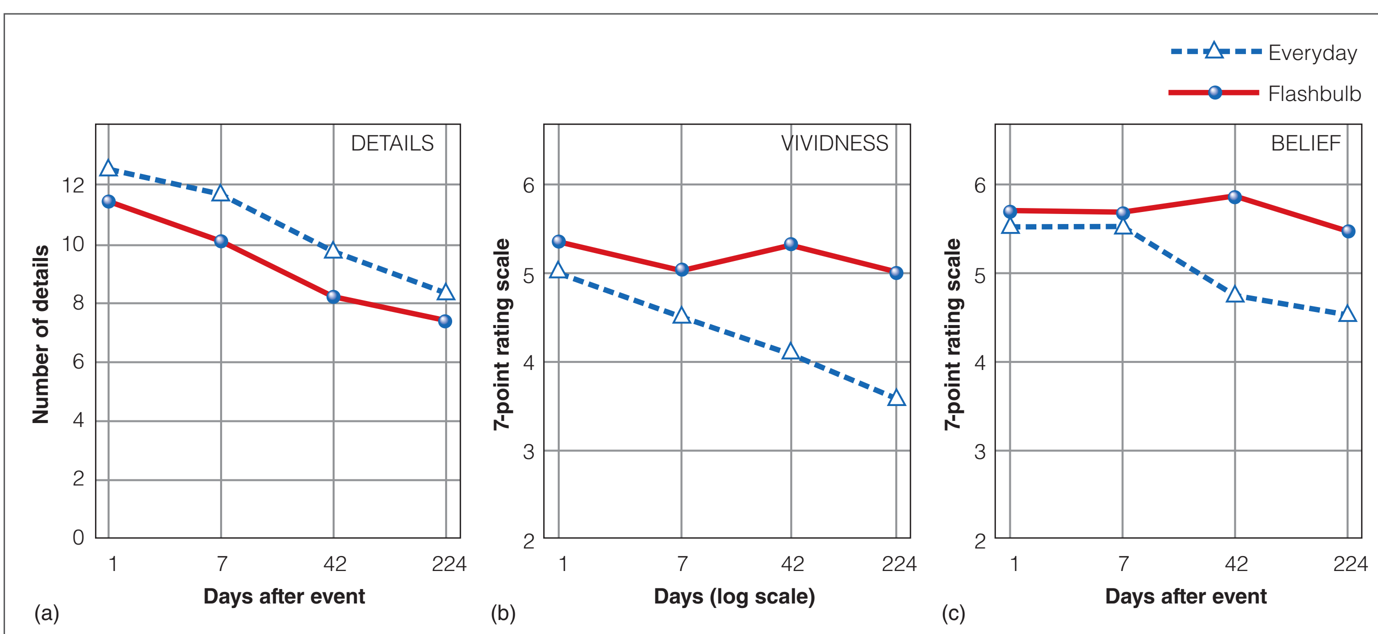


Figure 8.9 Results of Talarico and Rubin's (2003) flashbulb memory experiment: (a) details remembered; (b) vividness ratings; and (c) belief in accuracy. Details remembered decreased for both flashbulb and everyday memories. Belief in accuracy and vividness also decreased for everyday memories but remained high for flashbulb memories.

(Source: J. M. Talarico & D. C. Rubin, Confidence, not consistency, characterizes flashbulb memories, *Psychological Science*, 14, 455–461, Figures 1 & 2. Copyright © 2003 American Psychological Society. Reproduced by permission.)

TEST YOURSELF 8.1

1. How did people in a nationwide poll respond to the statement about how memory operates like a video camera? How accurate was their response?
2. What is autobiographical memory? What does it mean to say that it includes both episodic and semantic components?
3. What does it mean to say that autobiographical memories are multidimensional? How did Cabeza's photography experiment provide evidence for this idea?
4. What types of events are often the most memorable? What would a plot of "events remembered" versus "age" look like for a 50-year-old person? What theories have been proposed to explain the peak that occurs in this function?
5. What is the evidence that emotionally charged events are easier to remember than nonemotional events? Describe the role of the amygdala in emotional memory, including brain scan (fMRI) and neuropsychological (patient B.P.) evidence linking the amygdala and memory, and the experiment showing that emotion enhances consolidation.
6. What is the youth bias, and which explanation of the reminiscence bump is it associated with?
7. Why did Brown and Kulik call memory for public, emotional events, like the assassination of President Kennedy, "flashbulb memories"? Was their use of the term *flashbulb* correct?
8. Describe the results of repeated recall experiments. What do these results indicate about Brown and Kulik's "Now Print" proposal for flashbulb memories?
9. What is the narrative rehearsal hypothesis? How is the result of the Princess Diana study related to the effect of media coverage on memory?
10. In what ways are flashbulb memories different from other autobiographical memories and in what ways are they similar? What are some hypotheses explaining these differences?

The Constructive Nature of Memory

We have seen that we remember certain things better than others because of their special significance or because of when they happened in our lives. But we have also seen that what people remember may not match what actually happened. When people report memories for past events, they may not only omit things but also distort or change things that happened, and in some cases even report things that never happened at all.

These characteristics of memory reflect the **constructive nature of memory**—what people report as memories are constructed based on what actually happened plus additional factors, such as the person's knowledge, experiences, and expectations. One aspect of the constructive nature of memory is illustrated by the phenomenon of *source monitoring*.

Source Monitoring Errors

Imagine that there's a movie you can't wait to see because you heard it's really good. But when you try to remember what first turned you on to the movie, you're uncertain. Was it the review you read online? That conversation you had with a friend? The billboard you passed on the road? Can you remember the initial *source* that got you interested in the movie? This is the problem of **source monitoring**—the process of determining the origins of our memories, knowledge, or beliefs (Johnson et al., 1993). In searching your memory for when you first heard about the movie, if you decided it was the review you read online but in reality you first heard about it from your friend, you would have committed a **source monitoring error**—misidentifying the source of a memory.

Source monitoring errors are also called **source misattributions** because the memory is attributed to the wrong source. Source monitoring provides an example of the constructive nature of memory because when we remember something, we retrieve the memory ("I remember becoming interested in seeing that movie") and then determine where that memory came from ("It was that review I read online") (Mitchell & Johnson, 2000).

Source monitoring errors are common, and we are often unaware of them. Perhaps you have had the experience of remembering that one person told you about something but later realizing you had heard it from someone else—or the experience of claiming you had said something you had only thought ("I'll be home late for dinner") (Henkel, 2004). In the 1984 presidential campaign, President Ronald Reagan, running for reelection, repeatedly related a story about a heroic act by a U.S. pilot, only to have it revealed later that his story was almost identical to a scene from a 1940s war movie, *A Wing and a Prayer* (Johnson, 2006; Rogin, 1987). Apparently, the source of the president's reported memory was the film rather than an actual event.

Some of the more sensational examples of source monitoring errors are cases of **cryptomnesia**, unconscious plagiarism of the work of others. For example, Beatle George Harrison was sued for appropriating the melody from the song "He's So Fine" (originally recorded by the 1960s group the Chiffons) for his song "My Sweet Lord." Although Harrison claimed he had used the tune unconsciously, he was successfully sued by the publisher of the original song. Harrison's problem was that he thought he was the source of the melody, when the actual source was someone else.

An experiment by Larry Jacoby and coworkers (1989) titled "Becoming Famous Overnight" demonstrated a connection between source monitoring errors and familiarity by testing participants' ability to distinguish between famous and nonfamous names. In the acquisition part of the experiment, Jacoby had participants read a number of made-up nonfamous names like Sebastian Weissdorf and Valerie Marsh (**Figure 8.10**). For the immediate test group, participants were tested immediately after seeing the list of nonfamous names. They were told to pick out the names of famous people from a list containing (1) the nonfamous names they had just seen, (2) new nonfamous names that they had never seen before, and (3) famous names, like Minnie Pearl (a country singer) or Roger Bannister (the first person to run a 4-minute mile), that many people might have recognized in 1988, when the experiment was conducted. Just before this test, participants were reminded that all of the names they had seen in the first part of the experiment were nonfamous. Because the test was given shortly after the participants had seen the first list of nonfamous names,

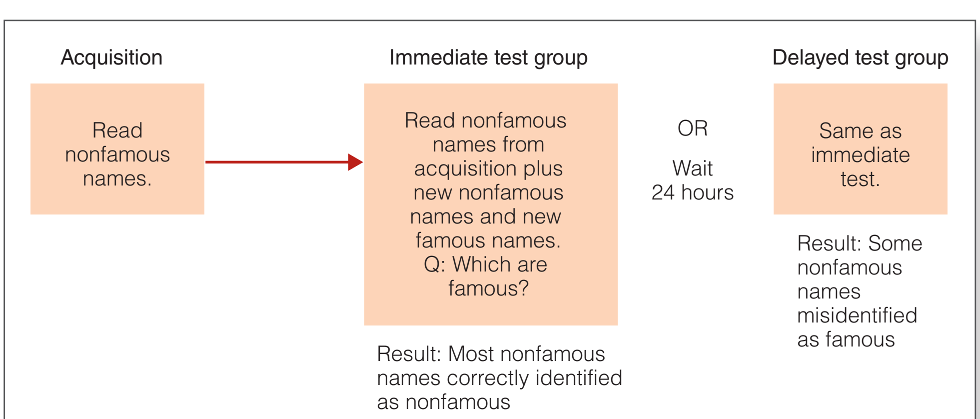


Figure 8.10 Design of Jacoby et al.'s (1989) "Becoming Famous Overnight" experiment.

they correctly identified most of the old nonfamous names (like Sebastian Weissdorf and Valerie Marsh) as being nonfamous.

The interesting result occurred for participants in the delayed test group, who were tested 24 hours after first seeing the names and, as for the other group, were told that the names they had seen in the first part of the experiment were nonfamous. When tested after this delay, participants were more likely to identify the old nonfamous names as being famous. Thus, waiting 24 hours before testing increased the chances that Sebastian Weissdorf would be labeled as famous.

How did Sebastian Weissdorf become famous overnight? To answer this question, put yourself in the place of one of Jacoby's participants. It is 24 hours since you saw the first list of nonfamous names, and you now have to decide whether Sebastian Weissdorf is famous or nonfamous. How do you make your decision? Sebastian Weissdorf doesn't pop out as someone you know of, but the name is familiar. You ask yourself the question, "Why is this name familiar?" This is a source monitoring problem, because to answer this question you need to determine the source of your familiarity. Are you familiar with the name Sebastian Weissdorf because you saw it 24 hours earlier or because it is the name of a famous person? Apparently, some of Jacoby's participants decided that the familiarity was caused by fame, so the previously unknown Sebastian Weissdorf became famous!

Later in the chapter, when we consider some of the issues involved in determining the accuracy of eyewitness testimony, we will see that situations that create a sense of familiarity can lead to source monitoring errors, such as identifying the wrong person as having been at the scene of a crime. Another demonstration of familiarity causing errors is the *illusory truth effect*.

The Illusory Truth Effect

Is the following sentence true or false? "Chemosynthesis is the name of the process by which plants make their food." If you said "false" you were right. ("Photosynthesis" is the actual process.) But one way to increase the chances that you might incorrectly state that the chemosynthesis statement is true is to have you read it once, and then again later. The enhanced probability of evaluating a statement as being true upon repeated presentation is called the **illusory truth effect** (Begg et al., 1992).

Lisa Fazio and coworkers (2015) presented both true and false statements to participants and then asked them to rate how *interesting* they were. Then, in the second part of the experiment, they asked participants to indicate whether the statements they had read previously, plus a number of new statements, were true or false. The results showed that new statements that were correct were rated "true" 56 percent of the time, but repeated statements that were correct were rated true 62 percent of the time. Similar results occurred for statements that were incorrect. Repetition increased perceived truth, even if the person knew the correct answer. So, reading an incorrect statement like "A Sari is the name of the short, pleated skirts worn by Scots" increased participants' later belief that it was true, even if they could correctly answer the question "What is the name of the short, pleated skirt worn by Scots?" (Answer: A kilt.)

Why does repetition increase perceived truthfulness? An answer proposed by Fazio is that **fluency**—the ease with which a statement can be remembered—influences people's judgments. This is similar to the idea that *familiarity* caused Sebastian Weissdorf to become perceived as famous in Jacoby's experiment. Thus, knowledge stored in memory is important (Fazio's participants were more likely to rate true statements as true), but fluency or familiarity can affect the judgments as well. The illusory truth effect is related to the propaganda effect discussed in Chapter 6 (page 184), because both are caused by repetition.

How Real-World Knowledge Affects Memory

The effects of creating familiarity on source monitoring illustrate how factors in addition to what actually happened can affect memory. We will now describe more examples, focusing on how our knowledge of the world can affect memory. A classic study that illustrates the effect of knowledge on memory was conducted before the first World War and was published in 1932 by Frederick Bartlett.

Bartlett's "War of the Ghosts" Experiment In this classic study, which was one of the first to suggest that memory was constructive, Bartlett had his participants read the following story from Canadian Indian folklore.

> The War of the Ghosts
>
> One night two young men from Egulac went down to the river to hunt seals, and while they were there it became foggy and calm. Then they heard war cries, and they thought: "Maybe this is a war party." They escaped to the shore and hid behind a log. Now canoes came up, and they heard the noise of paddles and saw one canoe coming up to them. There were five men in the canoe, and they said:
>
> "What do you think? We wish to take you along. We are going up the river to make war on the people."
>
> One of the young men said: "I have no arrows." "Arrows are in the canoe," they said. "I will not go along. I might be killed. My relatives do not know where I have gone. But you," he said, turning to the other, "may go with them."
>
> So one of the young men went, but the other returned home. And the warriors went on up the river to a town on the other side of Kalama. The people came down to the water, and they began to fight, and many were killed. But presently the young man heard one of the warriors say: "Quick, let us go home; that Indian has been hit." Now he thought: "Oh, they are ghosts." He did not feel sick, but they said he had been shot.
>
> So the canoes went back to Egulac, and the young man went ashore to his house and made a fire. And he told everybody and said: "Behold I accompanied the ghosts, and we went to fight. Many of our fellows were killed, and many of those who attacked us were killed. They said I was hit, and I did not feel sick."
>
> He told it all, and then he became quiet. When the sun rose, he fell down. Something black came out of his mouth. His face became contorted. The people jumped up and cried. He was dead. (Bartlett, 1932, p. 65)

After his participants had read this story, Bartlett asked them to recall it as accurately as possible. He then used the technique of **repeated reproduction**, in which the participants tried to remember the story at longer and longer intervals after they had first read it. This is similar to the repeated recall technique used in the flashbulb memory experiments (see Method: Repeated Recall, page 233).

One reason Bartlett's experiment is considered important is because it was one of the first to use the repeated reproduction technique. But the main reason the "War of the Ghosts" experiment is considered important is the nature of the errors Bartlett's participants made. At longer times after reading the story, most participants' reproductions of the story were shorter than the original and contained many omissions and inaccuracies. But what was most significant about the remembered stories is that they tended to reflect the participant's own culture. The original story, which came from Canadian folklore, was transformed by many of Bartlett's participants to make it more consistent with the culture of Edwardian England, to which they belonged. For example, one participant remembered the two men who were out hunting seals as being involved in a sailing expedition, the "canoes" as "boats," and the man who joined the war party as a fighter that any good Englishman would be proud of—ignoring his wounds, he continued fighting and won the admiration of the natives.

One way to think about what happened in Bartlett's experiment is that his participants created their memories from two sources. One source was the original story, and the other was what they knew about similar stories in their own culture. As time passed, the participants used information from both sources, so their reproductions became more like what would happen in Edwardian England. This idea that memories can be comprised of details from various sources is related to source monitoring, discussed earlier.

Making Inferences Memory reports can be influenced by inferences that people make based on their experiences and knowledge. In this section, we will consider this idea further. But first, do this demonstration.

DEMONSTRATION Reading Sentences

For this demonstration, read the following sentences, pausing for a few seconds after each one.

1. The children's snowman vanished when the temperature reached 80.
2. The flimsy shelf weakened under the weight of the books.
3. The absent minded professor didn't have his car keys.
4. The karate champion hit the cinder block.
5. The new baby stayed awake all night.

Now that you have read the sentences, turn to *Demonstration: Reading Sentences (Continued)* on page 258 and follow the directions.

How do your answers from the fill-in-the-blank exercise on page 258 compare to the words that you originally read in the Demonstration? William Brewer (1977) and Kathleen McDermott and Jason Chan (2006) presented participants with a similar task, involving many more sentences than you read, and found that errors occurred for about a third of the sentences. For the sentences above, the most common errors were as follows: (1) *vanished* became *melted*; (2) *weakened* became *collapsed*; (3) *didn't have* became *lost*; (4) hit became *broke* or *smashed*; and (5) *stayed awake* became *cried*.

These wording changes illustrate a process called **pragmatic inference**, which occurs when reading a sentence leads a person to expect something that is not explicitly stated or implied by the sentence (Brewer, 1977). These inferences are based on knowledge gained through experience. Thus, although reading that a baby stayed awake all night does not include any information about crying, knowledge about babies might lead a person to infer that the baby was crying (Chan & McDermott, 2006).

Here is the scenario used in another memory experiment, which was designed specifically to elicit inferences based on the participants' past experiences (Arkes & Freedman, 1984):

> In a baseball game, the score is tied 1 to 1. The home team has runners on first and third, with one out. A ground ball is hit to the shortstop. The shortstop throws to second base, attempting a double play. The runner who was on third scores, so it is now 2–1 in favor of the home team.

After hearing a story similar to this one, participants were asked to indicate whether the sentence "The batter was safe at first" was part of the passage. From looking at the story, you can see that this sentence was never presented, and most of the participants who didn't know much about baseball answered correctly. However, participants who knew the rules of baseball were more likely to say that the sentence had been presented. They based this judgment on their knowledge that if the runner on third had scored, then the double play must have failed, which means that the batter safely reached first. Knowledge, in this example, resulted in a correct inference about what probably happened in the ball game but an incorrect inference about the sentence that was presented in the passage.

Schemas and Scripts The preceding examples illustrate how people's memory reports can be influenced by their knowledge. A **schema** is a person's knowledge about some aspect of the environment. For example, a person's schema of a bank might include what banks often look like from the outside, the row of teller windows inside the bank, and the services a bank provides. We develop schemas through our experiences in different situations, such as making a deposit at a bank, going to a ball game, or listening to lectures in a classroom.

In an experiment that studied how memory is influenced by people's schemas, participants who had come to participate in a psychology experiment were asked to wait in an office (**Figure 8.11**) while the experimenter checked "to make sure that the previous hour's participant had completed the experiment." After 35 seconds, the participants were called into another room and were told that the purpose of the experiment was to test their memory for the office and that their task was to write down what they had seen while they were sitting in the office (Brewer & Treyens, 1981). The participants responded by writing down many of the things they remembered seeing, but they also included some things that were not there but that fit into their "office schema." For example, although there were no books in the office, 30 percent of the participants reported having seen books. Thus, the information in schemas can provide a guide for making inferences about what we remember. In this particular example, the inference turned out to be wrong.

➤ **Figure 8.11** Office where Brewer and Treyens's (1981) subjects waited before being tested on their memory for what was present in the office.

Other examples of how schemas can lead to erroneous decisions in memory experiments have involved a type of schema called a script. A **script** is our conception of *the sequence of actions* that usually occurs during a particular experience. For example, your coffee shop script might be waiting in line, ordering a drink and pastry from the barista, receiving the pastry, paying, and waiting near "pickup" for your drink.

Scripts can influence our memory by setting up expectations about what usually happens in a particular situation. To test the influence of scripts, Gordon Bower and coworkers (1979) did an experiment in which participants were asked to remember short passages like the following.

The Dentist

> Bill had a bad toothache. It seemed like forever before he finally arrived at the dentist's office. Bill looked around at the various dental posters on the wall. Finally the dental hygienist checked and x-rayed his teeth. He wondered what the dentist was doing. The dentist said that Bill had a lot of cavities. As soon as he'd made another appointment, he left the dentist's office. (Bower et al., 1979, p. 190)

The participants read a number of passages like this one, all of which were about familiar activities such as going to the dentist, going swimming, or going to a party. After a delay period, the participants were given the titles of the stories they had read and were told to write down what they remembered about each story as accurately as possible. The participants created stories that included much material that matched the original stories, but they also included material that wasn't presented in the original story but is part of the script for the activity described. For example, for the dentist story, some participants reported reading that "Bill checked in with the dentist's receptionist." This statement is part of most people's "going to the dentist" script, but it was not included in the original story. Thus, knowledge of the dentist script caused the participants to add information that wasn't originally presented. Another example of a link between knowledge and memory is provided by the following demonstration.

DEMONSTRATION Memory for a List

Read the following list at a rate of about one item per second; then cover the list and write down as many of the words as possible. In order for this demonstration to work, it is important that you cover the words and write down the words you remember before reading past the demonstration.

bed, rest, awake, tired, dream
wake, night, blanket, doze, slumber
snore, pillow, peace, yawn, drowsy

False Recall and Recognition The demonstration you just did is based on experiments by James Deese (1959) and Henry Roediger and Kathleen McDermott (1995), which were designed to illustrate false recall of items that were not actually presented. Does your list of remembered words include any words that are not on the preceding list? When I present this list to my class, there are always a substantial number of students who report that they remember the word "sleep." Remembering sleep is a false memory because it isn't on the list. This false memory occurs because people associate sleep with other words on the list. This is similar to the effect of schemas, in which people create false memories for office furnishings that aren't present because they associate these office furnishings with what is usually found in offices. Again, constructive processes have created an error in memory.

The crucial thing to take away from all of these examples is that false memories arise from the same constructive process that produces true memories. Thus, construction can cause memory errors, while at the same time providing the creativity that enables us to do things like understand language, solve problems, and make decisions. This creativity also helps us "fill in the blanks" when there is incomplete information. For example, when a person says "we went to the ball game," you have a pretty good idea of many of the things that happened in addition to the game (hot dogs or other ballpark food was likely involved, for example), based on your experience of going to a ball game.

What Is It Like to Have "Exceptional" Memory?

"OK," you might say, "the process of construction may help us do many useful things, but it certainly seems to cause trouble when applied to memory. Wouldn't it be great to have such exceptional memory that construction wouldn't be necessary?"

As it turns out, there are some people who have such good memory that they make few errors. One such person was the Russian memory expert Shereshevskii (S.), whose exceptional memory enabled him to make a living by demonstrating his memory powers on stage. After extensively studying S., Russian psychologist Alexandria Luria (1968) concluded that S.'s memory was "virtually limitless" (though Wilding & Valentine, 1997, pointed out that S. did occasionally make mistakes). But Luria also reported some problems: When S. performed a memory feat, he had trouble forgetting what he had just remembered. His mind was like a blackboard on which everything that happened was written and couldn't be erased. Many things flit through our minds briefly and then we don't need them again; unfortunately for S., these things stayed there even when he wished they would go away. He also was not good at reasoning that involved drawing inferences or "filling in the blanks" based on partial information. We do this so often that we take it for granted, but S.'s ability to record massive amounts of information, and his inability to erase it, may have hindered his ability to do this.

Recently, new cases of impressive memory have been reported; they are described as cases of **highly superior autobiographical memory** (LePort et al., 2012). One, a woman we will call A.J., sent the following email to UCLA memory researcher James McGaugh:

> I am 34 years old and since I was eleven I have had this unbelievable ability to recall my past. . . . I can take a date between 1974 and today, and tell you what day it falls on, what I was doing that day and if anything of great importance . . . occurred on that day I can describe that to you as well. . . . Whenever I see a date flash on the television (or anywhere else for that matter) I automatically go back to that day and remember where I was, what I was doing, what day it fell on and on and on and on and on. It is non-stop, uncontrollable and totally exhausting. . . . I run my entire life through my head every day and it drives me crazy!!! (Parker et al., 2006, p. 35)

A.J. describes her memories as happening automatically and not being under her conscious control. When given a date she would, within seconds, relate personal experiences and also special events that occurred on that day, and these recollections proved to be accurate when checked against a diary of daily events that A.J. had been keeping for 24 years (Parker et al., 2006).

A.J.'s excellent memory for personal experiences differed from S.'s in that the contents that she couldn't erase were not numbers or names from memory performances, but the details of her personal life. This was both positive (recalling happy events) and negative (recalling unhappy or disturbing events). But was her memory useful to her in areas other than remembering life events? Apparently, she was not able to apply her powers to help her remember material for exams, as she was an average student. And testing revealed that she had impaired performance on tests that involved organizing material, thinking abstractly, and working with concepts—skills that are important for thinking creatively. Following the discovery of A.J., a study of 10 additional participants confirmed their amazing powers of autobiographical memory recall, but they also performed at levels similar to normal control participants on most standard laboratory memory tests. Their skill therefore, seems to be specialized to remembering autobiographical memories (LaPort et al., 2012).

What the cases of S. and A.J. illustrate is that it is not necessarily an advantage to be able to remember everything; in fact, the mechanisms that result in superior powers of memory may work against the constructive processes that are an important characteristic not only of memory but of our ability to think creatively. Moreover, storing everything that is experienced is an inefficient way for a system to operate because too much storage can overload the system. To avoid this "overload," our memory system is designed to selectively remember things that are particularly important to us or that occur often in our environment (Anderson & Schooler, 1991). Although the resulting system does not record everything we experience, it has operated well enough to enable humans to survive as a species.

TEST YOURSELF 8.2

1. Source monitoring errors provide an example of the constructive nature of memory. Describe what source monitoring and source monitoring errors are and why they are considered "constructive."
2. Describe the "Becoming Famous Overnight" experiment. What does this experiment suggest about one cause of source monitoring errors?
3. Describe the illusory truth effect. Why does it occur?
4. Describe the following examples of how memory errors can occur because of a person's knowledge of the world: (1) Bartlett's "War of the Ghosts" experiment; (2) making inferences (pragmatic inference; baseball experiment); (3) schemas and scripts (office experiment; dentist experiment); (4) false recall and recognition ("sleep" experiment).
5. What is the evidence from clinical case studies that "super memory" may have some disadvantages? What are some advantages of constructive memory?

The Misinformation Effect

We've seen that our memory system is prone to error for a number of reasons. This section continues this theme, as we look at the **misinformation effect**—misleading information presented after a person witnesses an event can change how the person describes that event later. This misleading information is referred to as **misleading postevent information (MPI)**.

METHOD Presenting Misleading Postevent Information

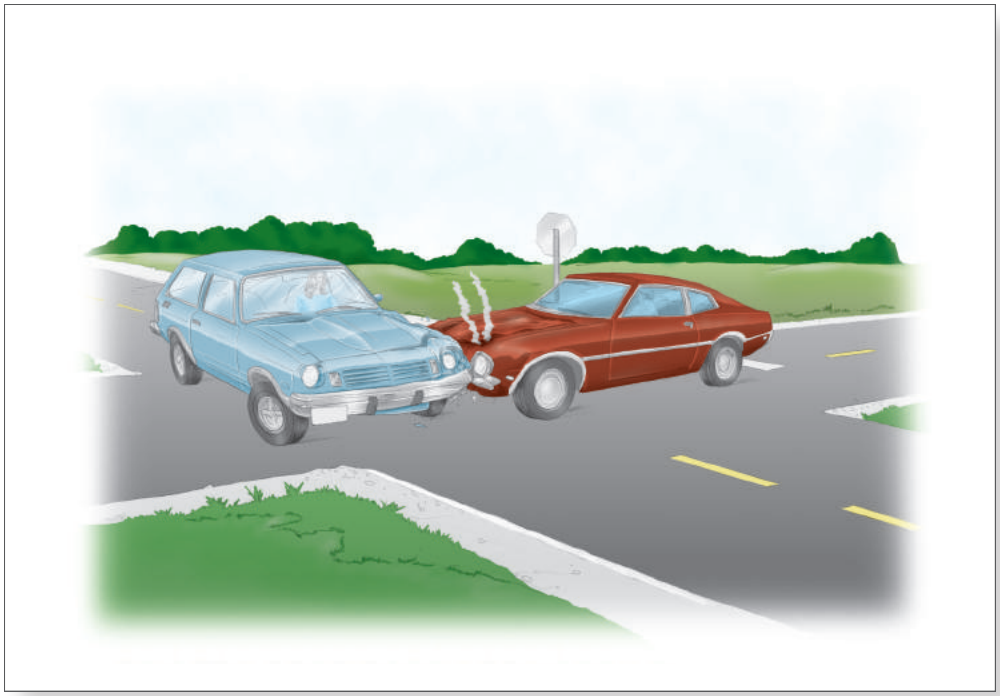
The usual procedure in an experiment in which MPI is presented is to first present the stimulus to be remembered. For example, this stimulus could be a list of words or a film of an event. The MPI is then presented to one group of participants before their memory is tested and is not presented to a control group. MPI is often presented in a way that seems natural, so it does not occur to participants that they are being misled. However, even when participants are told that postevent information may be incorrect, presenting this information can still affect their memory reports. The effect of MPI is determined by comparing the memory reports of participants who received this misleading information to the memory reports of participants who did not receive it.

An experiment by Elizabeth Loftus and coworkers (1978) illustrates a typical MPI procedure. Participants saw a series of slides in which a car stops at a stop sign and then turns the corner and hits a pedestrian. Some of the participants then answered a number of questions, including ones like, "Did another car pass the red Ford while it was stopped at the stop sign?" For another group of participants (the MPI group), the words "yield sign" replaced "stop sign" in the question. Participants were then shown pictures from the slide show plus some pictures they had never seen. Those in the MPI group were more likely to say they had seen the picture of the car stopped at the yield sign (which, in actuality, they had never seen) than were participants who had not been exposed to MPI. This shift in memory caused by MPI demonstrates the misinformation effect.

Presentation of MPI can alter not only what participants report they saw, but their conclusions about other characteristics of the situation. For example, Loftus and Steven Palmer (1974) showed participants films of a car crash (**Figure 8.12**) and then asked either (1) "How fast were the cars going when they smashed into each other?" or (2) "How fast were the cars going when they hit each other?" Although both groups saw the same event, the average speed estimate by participants who heard the word "smashed" was 41 miles per hour, whereas the estimates for participants who heard "hit" averaged 34 miles per hour. Even more interesting for the study of memory are the participants' responses to the question "Did you see any broken glass?" which Loftus asked 1 week after they had seen the film. Although there was no broken glass in the film, 32 percent of the participants who heard "smashed" before estimating the speed reported seeing broken glass, whereas only 14 percent of the participants who heard "hit" reported seeing the glass (see Loftus, 1993a, 1998).

One explanation for the misinformation effect is based on the idea of source monitoring. From the source monitoring perspective, a person incorrectly concludes that the source of his or her memory for the incorrect event (yield sign) was the slide show, even though the actual source was the experimenter's statement after the slide show.

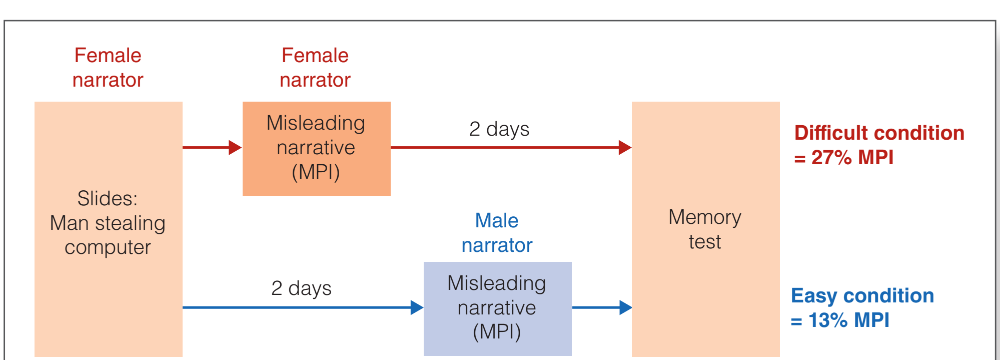
The following experiment by Stephen Lindsay (1990) investigated source monitoring and MPI by asking whether participants who are exposed to MPI really believe they saw something that was only suggested to them. Lindsay's participants first saw a sequence of



➤ **Figure 8.12** Participants in the Loftus and Palmer (1974) experiment saw a film of a car crash, with scenes similar to the picture shown here, and were then asked leading questions about the crash.

slides showing a maintenance man stealing money and a computer (**Figure 8.13**). This slide presentation was narrated by a female speaker, who simply described what was happening as the slides were being shown. The participants were then divided into two groups.

Participants in the *difficult condition* heard a misleading narrative shortly after seeing the slide presentation. This narrative was read by the same female speaker who had described the slide show. For example, when participants viewed the slide show, they saw Folgers coffee, but the misleading narrative said the coffee was Maxwell House. Two days later, participants returned to the lab for a memory test on the slide show. Just before the test, they were told that there were errors in the narrative story that they heard right after the slide show and that they should ignore the information in the story when taking the memory test.



➤ **Figure 8.13** Experimental design and results for Lindsay and coworkers' (1990) experiment.

Participants in the *easy condition* also heard the misleading story, but it was delayed for 2 days after the slide presentation, being presented right before they took the memory test. In addition, the story was read by a male speaker. As with the difficult group, these participants were also told to ignore the information presented in the misleading narrative.

The procedure for the difficult condition made it easy to confuse the misleading narrative and the narrated slide show because they occurred one after the other and were both read by the female. The results indicated that 27 percent of the responses of participants in the difficult condition matched the incorrect information that was presented in the misleading narrative. However, in the easy condition, it was easy to separate the misleading narrative from the slide show because they occurred 2 days apart and were read by different speakers. Only 13 percent of the responses for participants in the easy condition matched the misleading narrative. Source monitoring errors (including information from the misleading narrative) were therefore larger in the condition in which it was more difficult to tell the difference between the information presented in the slide show and the misleading narrative.

The experiments we've just described show that an experimenter's suggestion can influence people's memory reports for recently presented events (Loftus's "car crash" film; Lindsay's slide presentation of a robbery). But some of the most dramatic demonstrations of the effect of experimenter suggestion are situations in which suggestion causes people to "remember" events that occurred early in their lives, even though these events never happened.

Creating Memories for Events in People's Lives

A number of experiments have demonstrated how suggestion can influence memory for childhood events.

Creating Childhood Memories

Imagine that a person is in an experiment in which he or she is told about events that happened in his or her childhood. The experimenter provides brief descriptions of events that happened to the person long ago and asks the person to elaborate on each event. It isn't surprising that the person recognizes the events because the descriptions were provided to the experimenters by the person's parents. The person is therefore able to describe what they remember about the event, and sometimes also provide additional details.

But suddenly the person is stumped because the experimenter has described an event they don't remember. For example, here is a conversation that occurred in an experiment by Ira Hyman Jr. and coworkers (1995), in which a bogus event—one that never happened—was presented by the experimenter (E) to the participant (P):

E. At age 6 you attended a wedding reception, and while you were running around with some other kids you bumped into a table and turned a punch bowl over on a parent of the bride.
P: I have no clue. I have never heard that one before. Age 6?
E: Uh-huh.
P: No clue.
E: Can you think of any details?
P: Six years old; we would have been in Spokane, um, not at all.
E: OK.

However, in a second interview that occurred 2 days later, the participant responded as follows:

E: The next one was when you were 6 years old and you were attending a wedding.
P: The wedding was my best friend in Spokane, T___. Her brother, older brother, was getting married, and it was over here in P___, Washington, 'cause that's where

her family was from, and it was in the summer or the spring because it was really hot outside, and it was right on the water. It was an outdoor wedding, and I think we were running around and knocked something over like the punch bowl or something and um made a big mess and of course got yelled at for it.

E: Do you remember anything else?

P: No.

E: OK.

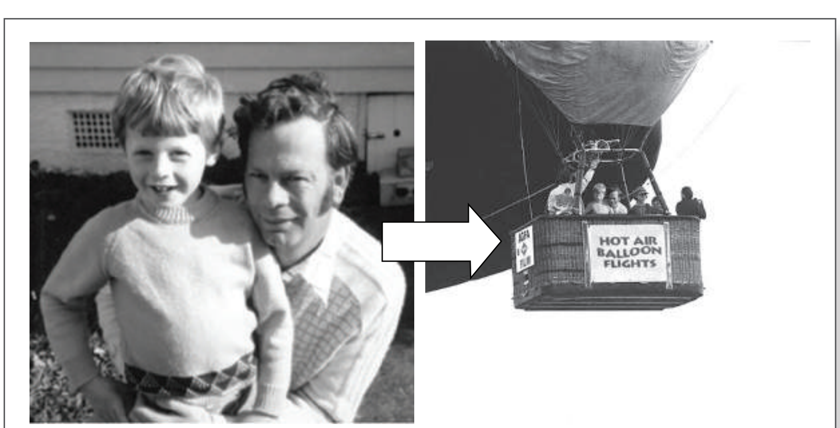
What is most interesting about this participant's response is that he didn't remember the wedding the first time but did remember it the second time. Apparently, hearing about the event and then waiting caused the event to emerge as a false memory. This can be explained by familiarity. When questioned about the wedding the second time, the participant's familiarity with the wedding from the first exposure caused him to accept the wedding as having actually happened.

In another childhood memory experiment, Kimberley Wade and coworkers (2002) showed participants photographs obtained from family members that showed the participant involved in various events like birthday parties or vacations when they were 4 to 8 years old. They also saw a photograph created in Photoshop that showed them in an event that never happened—taking a hot air balloon ride (**Figure 8.14**). They were shown the photo and asked to describe what they remembered about the event. If they couldn't remember the event, they were told to close their eyes and picture participating in the event.

Participants easily recalled the real events but initially didn't recall taking the hot air balloon ride. After picturing the event in their minds and further questioning, however, 35 percent of the participants "remembered" the balloon ride, and after two more interviews, 50 percent of the participants described their experience while riding in the balloon. This result is similar to the experiment described earlier in which participants were told that they had turned over a punch bowl at a wedding reception. These studies, and many others, have shown that people can be led to believe that they experienced something in their childhood that never actually happened (see Nash et al., 2017; Scorbia et al., 2017).

Legal Implications of False Memory Research

In the 1990s a number of highly publicized trials took place in which women who were being treated by therapists experienced a return of what has been called a **repressed childhood memory**—memories that have been pushed out of the person's consciousness. The



Psychonomic Bulletin & Review

➤ **Figure 8.14** How the stimulus for Wade and coworkers (2002) hot air balloon experiment was created. The image on the left was Photoshopped onto the balloon so it appeared that the child and his father went on a balloon ride.

hypothesis proposed by some therapists is that this repressed childhood memory can cause psychological problems and that the way to treat the patient's problem is to get them to retrieve the repressed memory. This accomplished using various techniques—hypnosis, guided imagery, strong suggestion—designed to "bring the memory back."

One such case involved 19-year-old Holly, who in the course of therapy for an eating disorder received a suggestion from her therapist that her disorder may have been caused by sexual abuse. After further therapy, which included additional suggestions from the therapist, Holly became convinced that her father had repeatedly raped her when she was a child. Holly's accusations caused her father, Gary Romona, to lose his $400,000-a-year executive job, his reputation, his friends, and contact with his three daughters.

Romona sued Holly's therapists for malpractice, accusing them of implanting memories in his daughter's mind. At the trial, Elizabeth Loftus and other cognitive psychologists described research on the misinformation effect and implanting false memories to demonstrate how suggestion can create false memories for long-ago events that never actually happened (Loftus, 1993b). Romona won a $500,000 judgment against the therapists. As a result of this case, which highlighted how memory can be influenced by suggestion, a number of criminal convictions based on "recovered memory" evidence have since been reversed.

The issues raised by cases like the Gary Romona case are complicated and disturbing. Child sexual abuse is a serious problem, which should not be minimized. But it is also important to be sure accusations are based on accurate information. According to a paper by the American Psychological Association (APA) Working Group on Investigation of Memories of Childhood Abuse, (1) most people who were sexually abused as children remember all or part of what happened to them; (2) it is possible for memories of abuse that have been forgotten for a long time to be remembered; and (3) it is also possible to construct convincing pseudomemories for events that never occurred. What's needed, suggests the APA and other researchers, is to educate both therapists and people in the criminal justice system about these research findings and make them aware of the sometimes tenuous relationship between what is remembered and what actually happened (Howe, 2013; Lindsay & Hyman, 2017; Nash et al., 2017).

Why Do People Make Errors in Eyewitness Testimony?

Continuing our theme of how memory research intersects with the criminal justice system, we now consider the issue of **eyewitness testimony**—testimony by someone who has witnessed a crime. Eyewitness testimony is, in the eyes of jury members, an extremely important source of evidence, because it is provided by people who were present at the crime scene and who are assumed to be doing their best to accurately report what they saw.

The acceptance of eyewitness testimony is based on two assumptions: (1) the eyewitness was able to clearly see what happened; and (2) the eyewitness was able to remember his or her observations and translate them into an accurate description of the perpetrator and what happened. The question then is, how accurate are witnesses' descriptions and identifications? What do you think the answer to this question is, based on what you know about perception, attention, and memory? The answer is that witness descriptions are often not very accurate, unless carried out under ideal conditions. Unfortunately, "ideal conditions" don't always occur, and there is a great deal of evidence that many innocent people have been convicted based on erroneous eyewitness identification.

Errors of Eyewitness Identification

In the United States, 300 people per day become criminal defendants based on eyewitness testimony (Goldstein et al., 1989). Unfortunately, there are many instances in which errors of eyewitness testimony have resulted in the conviction of innocent people. As of 2014, the use of DNA evidence had exonerated 349 people in the United States who had been wrongly convicted of crimes and served an average of 13 years in prison (Innocence Project, 2012; Time Special Edition, 2017). Seventy-five percent of these convictions involved eyewitness testimony (Quinlivan et al., 2010; Scheck et al., 2000).

To put a human face on the problem of wrongful convictions due to faulty eyewitness testimony, consider the case of David Webb, who was sentenced to up to 50 years in prison for rape, attempted rape, and attempted robbery based on eyewitness testimony. After serving 10 months, he was released after another man confessed to the crimes. Charles Clark went to prison for murder in 1938, based on eyewitness testimony that, 30 years later, was found to be inaccurate. He was released in 1968 (Loftus, 1979). Ronald Cotton was convicted of raping Jennifer Thompson in 1984, based on her testimony that she was extremely positive that he was the man who had raped her. Even after Cotton was exonerated by DNA evidence that implicated another man, Thompson still "remembered" Cotton as being her attacker. Cotton was released after serving 10 years (Wells & Quinlivan, 2009).

The disturbing thing about these examples is not only that they occurred, but that they suggest that many other innocent people are currently serving time for crimes they didn't commit. Many of these miscarriages of justice and others, some of which will undoubtedly never be discovered, are based on the assumption, made by jurors and judges, that people see and report things accurately.

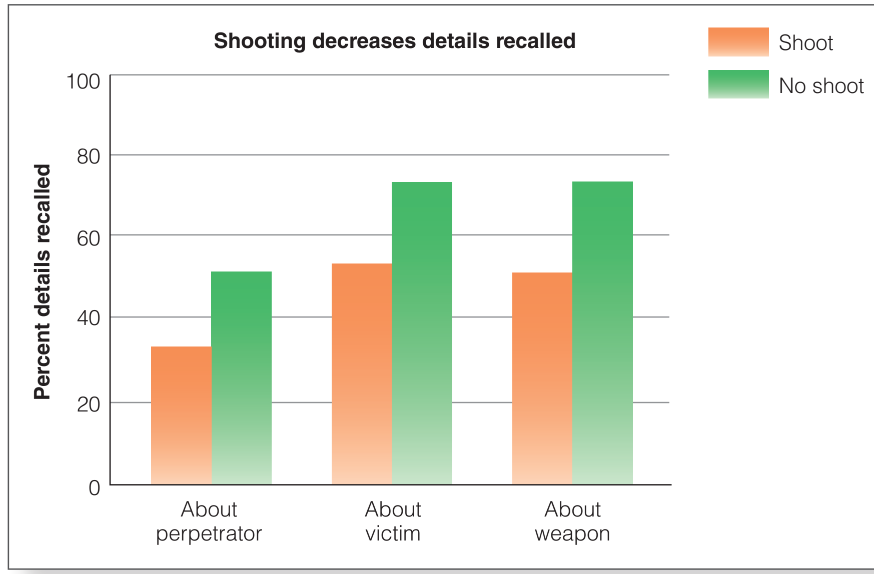
This assumption about the accuracy of testimony is based on the popular conception that memory works like a camera or video recorder, as demonstrated by the results of the nationwide survey described at the beginning of this chapter (page 226). Jurors carry these misconceptions about the accuracy of memory into the courtroom, and many judges and law enforcement officials also share these misconceptions about memory (Benton et al., 2006; Howe, 2013). So, the first problem is that jurors don't understand the basic facts about memory. Another problem is that the observations on which witnesses base their testimony are often made under the less than ideal conditions that occur at a crime scene, and then afterward, when they are talking with the police. We will now consider a few of the situations that can create errors.

Errors Associated with Perception and Attention

Witness reports will, of course, be inaccurate if the witness doesn't perceive what happened in the first place. There is ample evidence that identifications are difficult even when participants in laboratory experiments have been instructed to pay close attention to what is happening. A number of experiments have presented participants with films of actual crimes or staged crimes and then asked them to pick the perpetrator from a photo spread (photographs of a number of faces, one of which could be the perpetrator). In one study, participants viewed a security videotape in which a gunman was in view for 8 seconds and then were asked to pick the gunman from photographs. Every participant picked someone they thought was the gunman, even though his picture was not included in the photo spread (Wells & Bradfield, 1998; also see Kneller et al., 2001).

Studies such as this show how difficult it is to accurately identify someone after viewing a videotape of a crime and how strong the inclination is to pick someone. But things become even more complicated when we consider some of the things that happen during actual crimes. Emotions often run high during commission of a crime, and this can affect what a person pays attention to and what they remember later.

In a study of **weapons focus**, the tendency to focus attention on a weapon that results in a narrowing of attention, Claudia Stanny and Thomas Johnson (2000) determined how well participants remembered details of a filmed simulated crime. They found that participants were more likely to recall details of the perpetrator, the victim, and the weapon in the "no-shoot" condition (a gun was present but not fired) than in the "shoot" condition (the



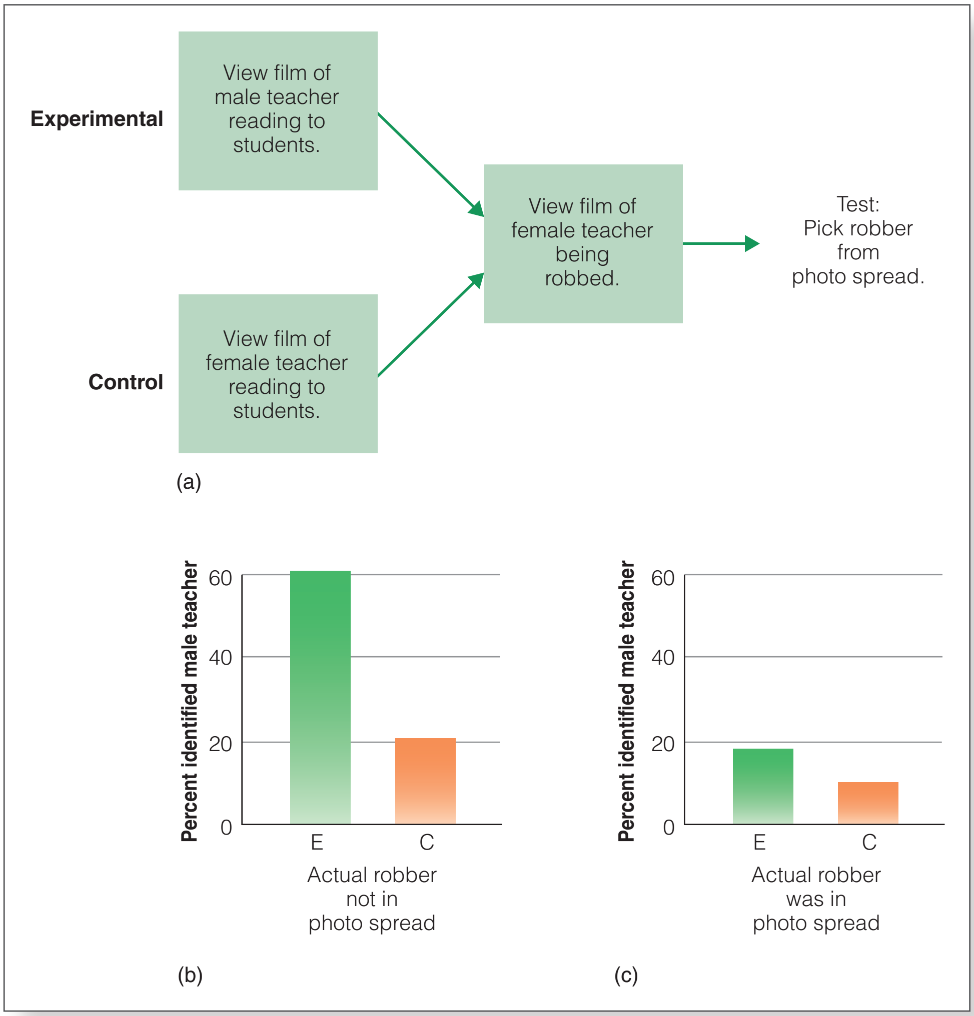
➤ **Figure 8.15** Results of Stanny and Johnson's (2000) weapons focus experiment. Presence of a weapon that was fired is associated with a decrease in memory about the perpetrator, the victim, and the weapon.

gun was fired; **Figure 8.15**). Apparently, the presence of a weapon that was fired distracted attention from other things that were happening (also see Tooley et al., 1987).

Misidentifications Due to Familiarity

Crimes not only involve a perpetrator and a victim but often include innocent bystanders (some of whom, as we will see, may not even be near the scene of the crime). These bystanders add yet another dimension to the testimony of eyewitnesses because there is a chance that a bystander could be mistakenly identified as a perpetrator because of familiarity from some other context. In one case of mistaken identification, a ticket agent at a railway station was robbed and subsequently identified a sailor as being the robber. Luckily for the sailor, he was able to show that he was somewhere else at the time of the crime. When asked why he identified the sailor, the ticket agent said that he looked familiar. The sailor looked familiar not because he was the robber, but because he lived near the train station and had purchased tickets from the agent on a number of occasions. This was an example of a source monitoring error. The ticket agent thought the source of his familiarity with the sailor was seeing him during the holdup; in reality, the source of his familiarity was seeing him when he purchased tickets. The sailor had become transformed from a ticket buyer into a holdup man by a source monitoring error (Ross et al., 1994).

Figure 8.16a shows the design for a laboratory experiment on familiarity and eyewitness testimony (Ross et al., 1994). Participants in the experimental group saw a film of a male teacher reading to students; participants in the control group saw a film of a female teacher reading to students. Participants in both groups then saw a film of the female teacher being robbed and were asked to pick the robber from a photo spread. The photographs did not include the actual robber, but did include the male teacher, who resembled the robber. The results indicate that participants in the experimental group, who had seen the male reading to the students, were three times more likely to pick the male teacher than were participants in the control group (**Figure 8.16b**). Even when the actual robber's face was included in the photo spread, 18 percent of participants in the experimental group picked the teacher, compared to 10 percent in the control group (**Figure 8.16c**). This is another example of how familiarity can result in errors of memory (see pages 238, 247).



➤ **Figure 8.16** (a) Design of Ross et al.'s (1994) experiment on the effect of familiarity on eyewitness testimony. (b) When the actual robber was not in the photo spread, subjects in the experimental group erroneously identified the male teacher as the robber 60 percent of the time. (c) When the actual robber was in the photo spread, the male teacher was identified 18 percent of the time.

Errors Due to Suggestion

From what we know about the misinformation effect, it is obvious that a police officer asking a witness "Did you see the white car?" could influence the witness's later testimony about what he or she saw. But suggestibility can also operate on a more subtle level. Consider the following situation: A witness to a crime is looking through a one-way window at a lineup of six men standing on a stage. The police officer says, "Which one of these men did it?" What is wrong with this question?

The problem with the police officer's question is that it implies that the perpetrator is in the lineup. This suggestion increases the chances that the witness will pick someone, perhaps using the following type of reasoning: "Well, the guy with the beard looks more like the robber than any of the other men, so that's probably the one." Of course, looking like the robber and actually being the robber may be two different things, so the result may be identification of an innocent man. A better way of presenting the task is to let the witness know that the crime suspect may or may not be in the lineup.

Here is another situation, taken from a transcript of an actual criminal case, in which suggestion could have played a role.

> Eyewitness to a crime on viewing a lineup: "Oh, my God. . . . I don't know. . . . It's one of those two . . . but I don't know. . . . . Oh, man . . the guy a little bit taller than number two. . . . It's one of those two, but I don't know."
>
> Eyewitness 30 minutes later, still viewing the lineup and having difficulty making a decision: "I don't know . . . number two?"
>
> Officer administering lineup: "Okay."
>
> Months later . . . at trial: "You were positive it was number two? It wasn't a maybe?"
>
> Answer from eyewitness: "There was no maybe about it. . . . I was absolutely positive." (Wells & Bradfield, 1998)

The problem with this scenario is that the police officer's response of "okay" may have influenced the witness to think that he or she had correctly identified the suspect. Thus, the witness's initially uncertain response turns into an "absolutely positive" response. In a paper titled "Good, You Identified the Suspect," Gary Wells and Amy Bradfield (1998) had participants view a video of an actual crime and then asked them to identify the perpetrator from a photo spread that did not actually contain a picture of the perpetrator (**Figure 8.17**).

All of the participants picked one of the photographs, and following their choice, witnesses received either confirming feedback from the experimenter ("Good, you identified the suspect"), no feedback, or disconfirming feedback ("Actually, the suspect was number —"). A short time later, the participants were asked how confident they were about their identification. The results, shown at the bottom of the figure, indicate that participants who received the confirming feedback were more confident of their choice.

Wells and Bradfield call this increase in confidence due to confirming feedback after making an identification the **post-identification feedback effect**. This effect creates a serious problem in the criminal justice system, because jurors are strongly influenced by how confident eyewitnesses are about their judgments. Thus, faulty eyewitness judgments can result in picking the wrong person, and the post-identification feedback effect can then increase witnesses' confidence that they made the right judgment (Douglass et al., 2010; Luus & Wells, 1994; Quinlivan et al., 2010; Wells & Quinlivan, 2009).

The fact that memories become more susceptible to suggestion during questioning means that every precaution needs to be taken to avoid making suggestions to the witness. This is often not done, but some steps have been taken to help improve the situation.

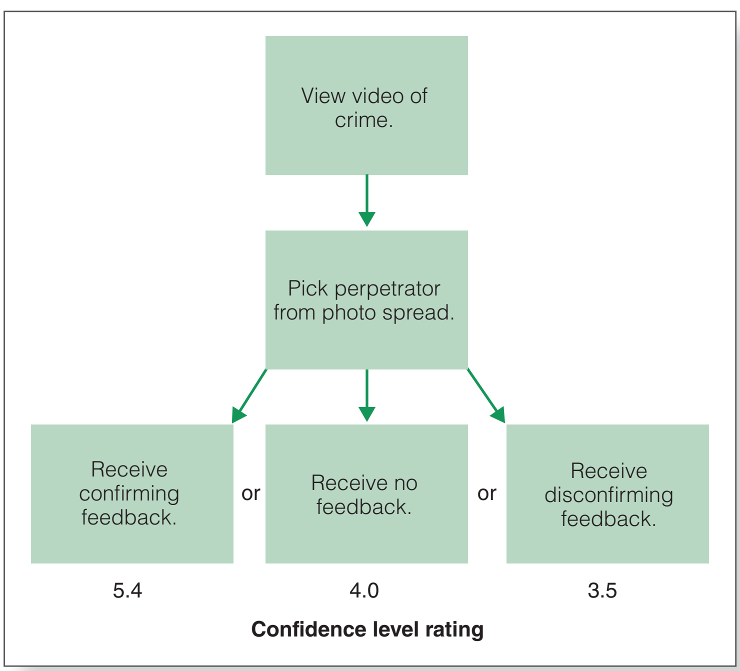


Figure 8.17 Design and results of Wells and Bradfield's (1998) "Good, You Identified the Suspect" experiment. The type of feedback from the experimenter influenced subjects' confidence in their identification, with confirming feedback resulting in the highest confidence.

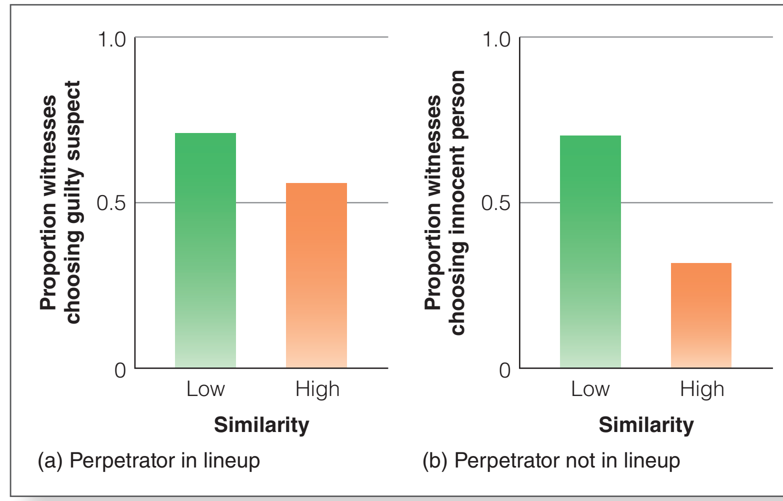
What Is Being Done to Improve Eyewitness Testimony?

The first step toward correcting the problem of inaccurate eyewitness testimony is to recognize that the problem exists. This has been achieved, largely through the efforts of memory researchers and attorneys and investigators for unjustly convicted people. The next step is to propose specific solutions. Cognitive psychologists have made suggestions about lineup procedures and interviewing procedures.

Lineup Procedures Lineups are notorious for producing mistaken identifications. Here are some of the recommendations that have been made:

Recommendation 1: When asking a witness to pick the perpetrator from a lineup, inform the witness that the perpetrator may not be in the particular lineup he or she is viewing. This is important because when a witness assumes that the perpetrator is in the lineup, this increases the chances that an innocent person who looks similar to the perpetrator will be selected. In one experiment, telling participants that the perpetrator may not be present in a lineup caused a 42 percent decrease in false identifications of innocent people (Malpass & Devine, 1981).

Recommendation 2: When constructing a lineup, use "fillers" who are similar to the suspect. When R. C. L. Lindsay and Gary Wells (1980) had participants view a tape of a crime scene and then tested them using high-similarity and low-similarity lineups, they obtained the results shown in **Figure 8.18**. When the perpetrator was in the lineup, increasing similarity did decrease identification of the perpetrator, from 0.71 to 0.58 (**Figure 8.18a**). But when the perpetrator was not in the lineup, increasing similarity caused a large decrease in incorrect identification of an innocent person, from 0.70 to 0.31 (**Figure 8.18b**). Thus, increasing similarity does result in missed identification of some guilty suspects but substantially reduces the erroneous identification of innocent people, especially when the perpetrator is not in the lineup (also see Charman et al., 2011).



➤ **Figure 8.18** Results of Lindsay and Wells's (1980) experiment, showing that (a) when the perpetrator was in the lineup, increasing similarity decreased identification of the perpetrator, but (b) when the perpetrator was not in the lineup, increasing similarity caused an even greater decrease in incorrect identification of innocent people.

Recommendation 3: Use a "blind" lineup administrator—someone who doesn't know who the suspect is. This reduces the chances that the expectations of the person administering the lineup will bias the outcome.

Recommendation 4: Have witnesses rate their confidence immediately—as they are making their identification. Research shows that high confidence measured at the time of identification is associated with more accurate identifications (Wixted et al., 2015, but that confidence at the time of the trial is not a reliable predictor of eyewitness accuracy (National Academy of Sciences, 2014).[1]

Interviewing Techniques We have already seen that making suggestions to the witness ("Good, you identified the suspect") can cause errors. To avoid this problem, cognitive psychologists have developed an interview procedure called the **cognitive interview**, which involves letting the witness talk with a minimum of interruption and also uses techniques that help witnesses recreate the situation present at the crime scene by having them place themselves back in the scene and recreate things like emotions they were feeling, where they were looking, and how the scene might have appeared when viewed from different perspectives (Memon et al., 2010).

[1] In the last edition of this book, an additional recommendation was listed: Use sequential lineups (where the witness views the lineup photographs one by one) rather than the more traditional simultaneous lineup (when all of the people in the lineup are viewed together). This recommendation was based on research that showed that sequential presentation lessened the chances of misidentifying an innocent person when the perpetrator isn't present. However, further experiments have led to the conclusion that it is unclear whether the sequential procedure is, in fact, better (National Academy of Sciences, 2014; Wells, 2015).

An important feature of the cognitive interview technique is that it decreases the likelihood of any suggestive input by the person conducting the interview. Comparisons of the results of cognitive interviews to routine police questioning have shown that the cognitive interview results in a large increase in reports of correct details. A disadvantage of the cognitive interview is that it takes longer than standard interviewing procedures. To deal with this problem, shorter versions have been developed (Fisher et al., 2013; Geiselman et al., 1986; Memon et al., 2010).

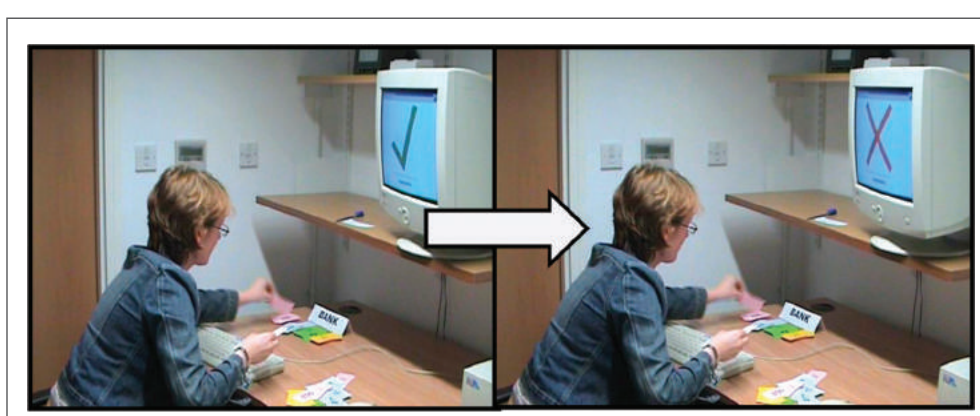
Eliciting False Confessions

We've seen that suggestion can influence the accuracy of what a witness reports as having happened in a crime scene. But let's take this a step further and ask whether suggestion can influence how someone who is suspected of committing a crime might respond to questioning about the crime. Let's begin with a laboratory experiment.

Robert Nash and Kimberley Wade (2009) took videos of participants as they played a computerized gambling game. Participants were told that on a trial in which they won their gamble, a green check would appear on the screen and they should take money from the bank, but when they lost, a red cross would appear and they should give money back to the bank. After participants had played the game, they were shown a doctored video in which the green check was replaced by the red cross to make them appear to be cheating by taking money when they were supposed to be giving it to the bank (**Figure 8.19**). When confronted with the video "evidence," some participants expressed surprise, but all confessed to cheating. In another group, who were told there was a video of them cheating (but who didn't see the video), 73 percent of the participants confessed.

False confessions such as this have also been demonstrated in other experiments, including one by Julia Shaw and Stephen Porter (2015) in which student participants were made to believe that they had committed a crime that involved contact with the police. Like the experiment in which participants were presented with true events that had happened in childhood, plus a false event like tipping over a punch bowl at a wedding reception (p. 246), participants in Shaw and Porter's experiment were presented with a true event that had occurred when they were between 11 and 14 years old, and a false event that they had not experienced. The false event involved committing a crime such as assault, assault with a weapon, or theft, which resulted in police contact.

When first presented with information about the true and false events, participants reported that they remembered the true event, but that they didn't remember committing



➤ **Figure 8.19** Stills from the video used by Nash and Wade (2009). The left panel is from the original video. The right panel is from the doctored video.

a crime. To induce creation of false memories for committing a crime, the interviewer used social pressure (statements like, "most people can retrieve lost memories if they try hard enough"), and provided instructions for a guided imagery procedure for visualizing the crime, which participants were told to practice every night at home.

When interviewed one- and two-weeks later, 70 percent of the participants reported that they did, in fact, remember the false event, and many reported details such as descriptions of the police officers. Thus, participants ended up believing they had committed a crime, and could provide details about the event, even though it never happened.

But it is one thing to admit to cheating or committing a crime in a laboratory experiment, and another thing to admit to a real crime, which might send you to jail. Flashback to a spring night in 1989, when a 28-year-old white woman was brutally raped and almost murdered while jogging through Central Park in New York. When five black and Hispanic teenage boys were brought in as suspects and were interrogated, all five eventually confessed to the crime. The boys came to be known as "The Central Park Five," and the case generated a huge amount of publicity. Although the police produced no physical evidence linking the boys to the crime, they were found guilty based on their confessions (which they had recanted shortly after being released from interrogation). They ended up spending a cumulative 41 years in prison. The only problem was that the boys were innocent.

Later, a convicted rapist and murderer, who was serving a life term, confessed to the crime—a confession that was backed up by DNA evidence found at the crime scene. The Central Park Five had their convictions vacated, and in 2003 they were awarded $41 million in compensation by New York City.

But, you might say, why would anyone confess to a crime they didn't commit, and, even more perplexing, why would five people confess to a crime they didn't commit? The answer to this question begins to emerge when we remember the laboratory "false confession" experiments we described above. In these experiments, participants confessed after rather mild suggestions from the experimenter, and some of them actually came to believe that they were "guilty."

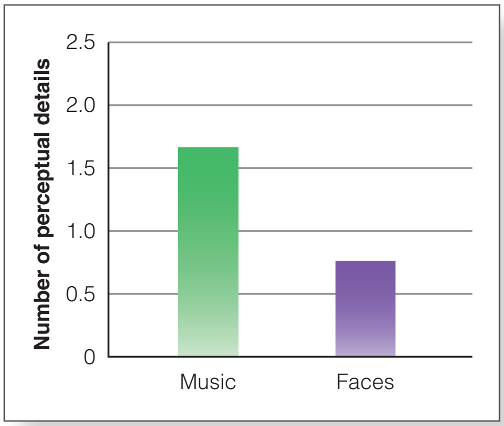
But the confessions of the Central Park Five occurred after 14 to 30 hours of aggressive interrogation, in which the boys were presented with false evidence indicating they were guilty. According to Saul Kassin, who has studied false confessions for over 35 years, most false confessions involve fake evidence presented to the suspect by the police (Nesterack, 2014). In response to research by Kassin and others, the Department of Justice now requires that interrogations by recorded. Additionally, Kassin argues that police should be prohibited from presenting suspects with false evidence. This recommendation remains to be acted on (see Kassin et al., 2010; Kassin, 2012, 2015).

SOMETHING TO CONSIDER

Music- and Odor-Elicited Autobiographical Memories

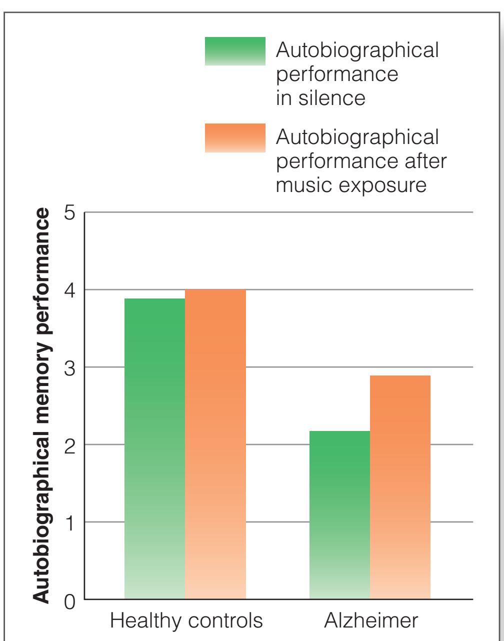
Walking along, not thinking about anything in particular, you enter a restaurant when—Bam!—out of the blue, a song playing in the background transports you back to a concert you attended over 10 years ago and also brings back memories about what was happening in your life when the song was popular. But in addition to just eliciting an autobiographical memory, the song also elicits emotions. Sometimes the memories elicited by music create a feeling called **nostalgia**, where nostalgia is defined as a memory that involves a sentimental affection for the past (Barrett et al., 2010). Memories elicited by hearing music are called **music-enhanced autobiographical memories (MEAMS)**.

These MEAMS are often experienced as being *involuntary memories*, because they occur as an automatic response to a stimulus (Berntsen & Rubin, 2008). This is in contrast to memories that require a conscious retrieval process, as might occur if you were asked to



➤ **Figure 8.20** The average number of perceptual details in memories reported by Belfi et al.'s (2016) participants for memories elicited by listening to music and memories elicited by looking at pictures of faces.

(Source: Belfi et al., *Memory,* 24 (7), Figure 3, page 984, 2016.)



➤ **Figure 8.21** The results of El Haj et al.'s (2013) experiment, which showed normal control participants (left pair of bars) had better autobiographical memory than Alzheimer's patients (right pair of bars), and that the Alzheimer's patients' autobiographical memory was enhanced by listening to music that was meaningful to them.

(Source: El Haj et al., *Journal of Neurolinguistics*, 26, Fig 1, page 696, 2013.)

think back to your earliest memory or to remember what happened on the day you first arrived at college (Jack & Hayne, 2007; Janata et al., 2007).

The power of sensory experiences to elicit autobiographical memories was made famous in literature by Marcel Proust's (1922/1960) description, in his novel *Remembrance of Things Past*, of an experience after eating a small lemon cookie called a madeleine:

> "The sight of the little madeleine had recalled nothing to my mind before I tasted it … as soon as I had recognized the taste of the piece of madeleine soaked in her decoction of lime-blossom which my aunt used to give me … immediately the old grey house upon the street, where her room was, rose up like a stage set to attach itself to the little pavilion opening on to the garden which had been built out behind it for my parents … and with the house the … square where I used to be sent before lunch, the streets along which I used to run errands, the country roads we took when it was fine.

Proust's description of how taste and olfaction unlocked memories he hadn't thought of for years, now called the **Proust effect**, is not an uncommon experience, and it has also been observed in the laboratory. Rachel Herz and Jonathan Schooler (2002) had participants describe a personal memory associated with items like Crayola crayons, Coppertone suntan lotion, and Johnson's baby powder. After describing their memory associated with the objects, they were presented with an object either in visual form (a color photograph) or in odor form (smelling the object's odor) and were asked to think about the event they had described and to rate it on a number of scales. The result was that participants who smelled the odor rated their memories as more emotional than participants who saw the picture. They also had a stronger feeling than the visual group of "being brought back" to the time the memory occurred (also see Chu & Downes, 2002; Larsson & Willander, 2009; Reid et al., 2015; Toffolo et al., 2012).

High emotionality and detail have also been observed for music-elicited autobiographical memories. For example, Amy Belfi and coworkers (2016) demonstrated that music evokes vivid autobiographical memories. Their participants either listened to musical excerpts of songs popular when the participant was 15 to 30 years old or looked at pictures of faces of famous people who were popular during that age span. This range was picked because it corresponds to the reminiscence bump, which is when autobiographical memories are most likely (see page 228).

For songs and pictures that participants rated as being "autobiographical," the memories they described tended to be more vivid and detailed for the memories elicited by music than for the memories elicited by faces (**Figure 8.20**). In addition to eliciting detailed memories, MEAMS tend to elicit strong emotions (El Haj et al., 2012; Janeta et al., 2007).

The power of music to evoke memories has also been demonstrated in people with memory impairments caused by Alzheimer's disease. Mohamad El Haj and coworkers (2013) asked healthy control participants and participants with Alzheimer's to respond to the instruction "describe in detail an event in your life" after (1) two minutes of silence or (2) two minutes of listening to music that they had chosen. The healthy controls were able to describe autobiographical memories equally well in both conditions, but the memory of Alzheimer's patients was better after listening to the music (**Figure 8.21**).

The ability of music to elicit autobiographical memories in Alzheimer's patients inspired the film *Alive Inside* (Rossato-Bennett, director, 2014), which won the audience award at the 2014 Sundance Film Festival. This film documents the work of a nonprofit organization called Music & Memory (musicandmemory.org),

➤ **Figure 8.22** Stills from the film *Alive Inside*. (a) Henry in his usual unresponsive state. (b) Henry listening and singing along with music that was meaningful to him. Listening to music also enhanced Henry's ability to talk with his caregivers.

which has distributed iPods to hundreds of long-term care facilities for use by Alzheimer's patients. In a memorable scene, Henry, who suffers from severe dementia, is shown immobile and unresponsive to questions and what is going on around him (**Figure 8.22a**). But when the therapist puts earphones on Henry and turns on the music, he comes alive. He starts moving to the beat. He sings along with the music. And, most important of all, memories that had been locked away by Henry's dementia are released, and he becomes able to talk about some things he remembers from his past (**Figure 8.22b**).

TEST YOURSELF 8.3

1. Describe experiments showing that memory can be affected by suggestion, which led to the proposal of the misinformation effect.
2. Describe Lindsay's experiment involving a maintenance man stealing. What does this experiment suggest about one of the causes of the misinformation effect?
3. How has it been shown that suggestion can influence people's memories for early childhood events?
4. Describe the idea of repressed childhood memory. How has it led to legal cases? What does the American Psychological Association's "white paper" say about repressed memories?
5. What is the evidence, both from "real life" and from laboratory experiments, that eyewitness testimony is not always accurate? Describe how the following factors have been shown to lead to errors in eyewitness testimony: weapons focus, familiarity, leading questions, feedback from a police officer, and postevent questioning.
6. What procedures have cognitive psychologists proposed to increase the accuracy of (a) lineups and (b) interviewing techniques?
7. Describe two laboratory experiments that elicited false confessions from participants.
8. Describe the case of the "Central Park Five." What implications does this case have for criminal interrogation procedures?
9. Describe examples of how odor and music can enhance autobiographical memories. How have music-enhanced autobiographical memories been used with Alzheimer's patients?

DEMONSTRATION Reading Sentences (Continued)

The sentences below are the ones you read in the demonstration on page 240 but with one or two words missing. Without looking back at the original sentences, fill in the blanks with the words that were in the sentences you initially read.

The flimsy shelf _______ under the weight of the books.
The children's snowman _______ when the temperature reached 80.
The absentminded professor _______ his car keys.
The new baby _______ all night.
The karate champion _______ the cinder block.

After doing this, return to page 240 and read the text that follows the demonstration.

CHAPTER SUMMARY

1. A nationwide poll has shown that a substantial proportion of people have erroneous conceptions about the nature of memory.
2. Autobiographical memory has been defined as memory for specific experiences from our life. It consists of both episodic and semantic components.
3. The multidimensional nature of autobiographical memory has been studied by showing that people who have lost their visual memory due to brain damage experience a loss of autobiographical memory. Also supporting the multidimensional nature of autobiographical memory is Cabeza's experiment, which showed that a person's brain is more extensively activated when viewing photographs taken by the person himself or herself than when viewing photographs taken by someone else.
4. When people are asked to remember events over their lifetime, transition points are particularly memorable. Also, people over age 40 tend to have good memory for events they experienced from adolescence to early adulthood. This is called the *reminiscence bump*.
5. The following hypotheses have been proposed to explain the reminiscence bump: (1) self-image, (2) cognitive, and (3) cultural life script.
6. Emotions are often associated with events that are easily remembered. The amygdala is a key structure for emotional memories, and emotion has been linked to improved memory consolidation.
7. Brown and Kulik proposed the term *flashbulb memory* to refer to a person's memory for the circumstances surrounding hearing about shocking, highly charged events. They proposed that these flashbulb memories are vivid and detailed, like photographs.
8. A number of experiments indicate that it is not accurate to equate flashbulb memories with photographs because, as time passes, people make many errors when reporting flashbulb memories. Studies of memories for hearing about the *Challenger* explosion showed that people's responses became more inaccurate with increasing time after the event.
9. Talarico and Rubin's study of people's memory for when they first heard about the 9/11 terrorist attack indicates that memory errors increased with time, just as for other memories, but that the 9/11 memories were more vivid and people remained more confident of the accuracy of their 9/11 memory.
10. The narrative rehearsal hypothesis proposes that enhanced memory for significant events may be caused by rehearsal. This rehearsal is often linked to TV coverage, as illustrated by the results of the Princess Diana study.
11. According to the constructive approach to memory, originally proposed by Bartlett based on his "War of the Ghosts" experiment, what people report as memories are constructed based on what actually happened plus additional factors such as the person's knowledge, experiences, and expectations.
12. Source monitoring is the process of determining the origins of our memories, knowledge, or beliefs. A source monitoring error occurs when the source of a memory is misidentified. Cryptomnesia (unconscious plagiarism) is an example of a source monitoring error.