

01 - 8 Memory

8 Memory

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In December 1986, a man named Ronald Cotton went on trial, accused of brutally raping a university student named Jennifer Thompson. From the witness stand, Ms. Thompson testified that during her ordeal, which occurred in the nighttime darkness of her apartment bedroom, she intently studied the rapist's face. In a newspaper column, written 15 years later, she stated that, 'I looked at his hairline; I looked for scars, for tattoos, for anything that would help me identify him.' Based on what she presumed to be the resulting very strong memory of her attacker's appearance, she confidently identified Mr. Cotton as the man who raped her. Based on Ms. Thompson's identification, Mr. Cotton, despite a strong alibi for the night in question, was convicted and was sentenced by the judge to serve life plus 54 years. On the face of it, it would seem that the jury did the right thing in convicting Mr. Cotton: Alibi or no, Ms. Thompson's identification was pretty convincing. She described, as recounted above, the vivid memory she had formed of her attacker's appearance; she eventually picked Mr. Cotton out of a collection of police photos; she picked him again out of a police lineup; and her trial testimony left the jury with no doubt that she believed she had picked the right man. As she later wrote, 'I knew this was the man. I was completely confident. I was sure. . . . If there was the possibility of a death sentence, I wanted him to die. I wanted to flip the switch.' As the years passed, Ronald Cotton appealed his conviction from his jail cell, always maintaining his innocence. Eventually, another man, a prison inmate, Bobby Poole was discovered to have boasted to his cellmates about having committed the rape for which Mr. Cotton had been convicted. As a precaution, Jennifer Thompson was shown Mr. Poole and asked about the possibility that he, not Mr. Cotton could have been her attacker. Ms. Thompson stuck to her guns, proclaiming confidently, 'I have never seen this man [Bobby Poole] in my life. I have no idea who he is.' But Jennifer Thompson was wrong, both in her identification of Ronald Cotton and in her rejection of Bobby Poole as the man who raped her. After serving 11 years in prison, Mr. Cotton was exonerated of the crime by the emerging science of DNA matching; moreover, the same evidence confirmed that Bobby Poole was indeed the rapist. Jennifer Thompson, finally convinced of her false memory, but profoundly shocked by it, became a strong advocate of extreme caution when convicting a defendant solely on the basis of someone's memory. For more Cengage Learning textbooks, visit www.cengagebrain.co.uk

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272 CHAPTER 8 MEMORY In their landmark book *Actual Innocence*, Barry Scheck, Peter Newfeld,
and Jim Dwyer described the Innocence Project, a program devoted to using DNA evidence as a
means of exonerating the falsely accused. In their accounts of dozens of other plights similar to
that of Ronald Cotton, the authors note that, 'In a study of DNA exonerations, by the Innocence
Project, 84% of the wrongful convictions rested, at least in part, on mistaken identification by an
eyewitness or victim', and they go on to point out that, dramatic as these results are, they only
confirm a century of social science research and judicial fact finding. It is, in large part, this
research with which we are concerned in this chapter. Our memories are usually more or less
correct – if they weren't, we'd have a tough go of it through life. However, they are incorrect more
often than we might think, and sometimes the consequences of incorrect memories are dramatic.
THREE IMPORTANT DISTINCTIONS Psychologists today make three major distinctions about
memory. The first concerns three stages of memory: encoding, storage, and retrieval. The second
deals with different memories for storing information for short and long periods. The third
distinction is about different memories being used to store different kinds of information (for
example, one system for facts and another for skills). For each of these distinctions, there is
evidence that the entities being distinguished – say, working versus longterm memory – are
mediated in part by different structures in the brain. Three stages of memory Suppose that you are
introduced to another student and told that her name is Barbara Cohn. That afternoon you see her
again and say something like, 'You're Barbara Cohn. We met this morning.' Clearly, you have
remembered her name. But how exactly did you remember it? This memory feat can be divided
into three stages (see Figure 8.1). First, when you were introduced, you somehow entered Barbara
Cohn's name into memory; this is the encoding stage. You transformed a physical input (sound
waves) corresponding to her spoken name into the kind of code or representation that memory
accepts, and you 'placed' that representation in memory; you likewise transformed another
physical input, the pattern of light corresponding to her face, into a memory for her face; and you
connected the two representations. Second, you retained – or stored – the information
corresponding to For more Cengage Learning textbooks, visit www.cengagebrain.co.uk A moment's
thought should convince you that the memory is the most critical mental facility we possess with
regard to our ability to operate as humans. It is based on memory of one sort or another, that we
make almost all decisions about what to do. Even a person deprived of the sensory input that most
of us take for granted – for instance a blind and deaf person like Helen Keller – is entirely capable of
living a superbly fulfilling life. In contrast, as is attested by anyone who knows a person ravaged by
Alzheimer's disease, even with normal sensory input, lack of memory is profoundly debilitating. It is
not surprising, therefore, that memory is the focus of a great amount of research, both in

psychology and in the biological sciences; and in this chapter we describe a small portion of that research. To appreciate the scientific study of memory, however, we need to understand how researchers divide the field into manageable units. her name and her face during the time between the two meetings; this is the storage stage. Third, based on the stored representation of her face, you recognized her in the afternoon as someone you had met in the morning and, based on this recognition, you recovered her name ^a ISTOCKPHOTO.COM/SCOTT DUNLAP Memory has three stages. The first stage, encoding, consists of placing a fact in memory. This occurs when we study. The second stage is storage, when the fact is retained in memory. The third stage, retrieval, occurs when the fact is recovered from storage – for example, when we take an exam.

RETRIEVAL ENCODING STORAGE Maintain in memory Recover from memory Put into memory
Figure 8.1 Three Stages of Memory. Theories of memory attribute forgetting to a failure at one or more of these stages. (A. W. Melton (1963) 'Implication of Short-Term Memory for a General Theory of Memory' from Journal of Verbal Learning and Verbal Behavior, 2:1-21. Adapted by permission of the Academic Press.) ^a ROB LACEY / VIVIDSTOCK.NET / ALAMY Jazz pianist Herbie Hancock in concert. Recent evidence indicates that we use a different long-term memory for storing skills like the ability to play the piano than we do for retaining facts. from storage at the time of your second meeting. All of this is the retrieval stage. Memory can fail at any of these three stages. Had you been unable to recall Barbara's name at the second meeting, this could have reflected a failure in encoding (you didn't properly store her face to begin with), in storage (you forgot her name somewhere along the way), or retrieval (you hadn't connected her name to her face in such a way that you could conjure up one from the other). Much of current research on memory attempts to specify the mental operations that occur at each of the three stages of memory and explain how these operations can go awry and result in memory failure. A number of recent studies suggest that the different stages of memory are mediated by different structures in the brain. The most striking evidence comes from brainscanning studies. These experiments involve two parts. In Part 1, which focuses on encoding, participants study a set of verbal items – for example, pairs consisting of categories and uncommon instances (furniture-sideboard); in Part 2, which focuses on retrieval, participants have to recognize or recall the items when cued with the category name. In both parts, positron emission tomography (PET) measures of brain activity are recorded while participants are engaged in their task. The most striking finding is that during encoding most of the activated brain regions are in the left hemisphere, whereas during For more Cengage Learning textbooks, visit www.cengagebrain.co.uk THREE IMPORTANT DISTINCTIONS retrieval most of the activated brain areas are in the right hemisphere (Shallice et al., 1994; Tulving et al., 1994). Three memory stores The three stages of memory do not operate the same way in all situations. Memory processes differ between situations that require us to store material (1) for less than a second, (2) for a matter of seconds and (3) for longer intervals ranging from minutes to years. The Atkinson-Shiffrin theory A classic basis for the distinction between different memories corresponding to different time intervals was formalized by Richard Atkinson and Richard Shiffrin in 1968. The basic tenets of this theory were as follows.

1. Information arriving from the environment is first placed into what was termed sensory store, which has the following characteristics (see Massaro & Loftus, 1996). First it is large – the sensory store pertaining to a given sense organ contained all the information impinging on that sense organ from the environment. Second, it is transient. Information from sensory store decayed over a time period ranging from a few tenths of a second for

visual sensory store to a few seconds for auditory sensory store. Third, that small portion of information in sensory store that was attended to (see Chapter 5) was transferred out of sensory store into the next major component of the system, short-term memory.

2. Short-term memory is, as just indicated, the next repository of information. Short-term memory has the following characteristics. First, it can be roughly identified with consciousness; information in short-term memory is information that you are conscious of. Second, information in short-term memory is readily accessible; it can be used as the foundation of making decisions or carrying out tasks in times on the order of seconds or less. Third, all else being equal, information in short-term memory will decay – will be forgotten – over a period of approximately 20 seconds. Fourth, information can be prevented from decaying if it is rehearsed, that is, repeated over and over (see Sperling, 1967). Fifth, information that is rehearsed, as just defined, or that undergoes other forms of processing, collectively known as elaboration (for example, being transformed into a suitable visual image) is transferred from short-term memory into the third repository of information, long-term store.
3. Long-term store is, as the name implies, the large repository of information in which is maintained all information that is generally available to us. Long-term store has the following characteristics. First, as just

274 CHAPTER 8 MEMORY indicated, information enters it via various kinds of elaborative processes, from short-term memory. Second, the size of long-term store is, as far as is known, unlimited. Third, information is acquired from long-term store via the process of retrieval (discussed briefly above) and placed back into short-term memory where it can be manipulated and used to carry out the task at hand. Different memories for different kinds of information Until about three decades ago, psychologists generally assumed that the same memory system was used for all kinds of memories. For example, the same long-term memory was presumably used to store both one's recollection of a grandmother's funeral and the skills one needs to ride a bike. More recent evidence indicates that this assumption is wrong. In particular, we seem to use a different long-term memory for storing facts (such as who had lunch with us yesterday) than we do for retaining skills (such as how to ride a bicycle). The evidence for this difference, as usual, includes both psychological and biological findings; these are considered later in the chapter. The kind of memory situation that we understand best is explicit memory, in which a person consciously recollects an event in the past, where this recollection is experienced as occurring in a particular time and place. In contrast, implicit memory is one in which a person unconsciously remembers information of various sorts – for example, information required to carry out some physical task such as kicking a soccer ball. INTERIM SUMMARY I There are three stages of memory: encoding, storage, and retrieval. There is increasing biological evidence for these distinctions. Recent brain-scanning studies of long-term memory indicate that most of the brain regions activated during encoding are in the left hemisphere and that most of the regions activated during retrieval are in the right hemisphere. I There are three kinds of memory that differ in terms of their temporal characteristics: Sensory memory lasts over a few hundreds of milliseconds; short-term store (now called working memory) operates over seconds; long-term store operates over times ranging from minutes to years. I Explicit memory is conscious, and implicit memory is unconscious. For more Cengage Learning textbooks, visit www.cengagebrain.co.uk CRITICAL THINKING QUESTIONS 1 Suppose that a friend complained to you, 'I have a terrible memory?' What questions might you ask in view of what you've just learned about memory in this section? SENSORY MEMORY The

information initially acquired from the environment via the sense organs is placed into a short-lasting memory called sensory memory. We have briefly described sensory memory: It holds a large amount of information, it holds a fairly faithful representation of the sensory information that enters the sense organ, and it is short-lasting. When you have the dramatic experience of seeing an otherwise dark world briefly lit up by a lightning flash, you are experiencing the sensory memory corresponding to vision, called iconic memory. There are probably sensory memories corresponding to all sensory modalities, but, as with sensation and perception, those that have been studied most extensively are the ones corresponding to vision (iconic memory) and to audition (echoic memory). For purposes of brevity we will, in what follows, concentrate on the most-studied sensory memory, iconic memory. Sperling's experiments: the partial-report experiment In 1960, George Sperling published a seminal paper based on his Harvard doctoral dissertation. Sperling began with the observation that when people were briefly presented with a large amount of information – say 12 digits arranged as three rows of four columns per row – they typically could only report about 4 or 5 of the digits. This amount, known as the span of apprehension had been known for almost a century and was assumed to represent the maximum amount of information a person could acquire from such an informational array. However, people had two intuitions that indicated that things were not quite so simple. The first was that they were able to see more than they could report but that they quickly forgot it: 'By the time we are able to write down 4 or 5 digits', they complained, 'we can't remember the rest of the display any more'. The second intuition was that the image of the display appeared to persist longer than the display itself. Both these intuitions are easy to demonstrate: Go into a pitch-dark closet with a book; open the book to a random page, and fire a flash with a camera (the picture doesn't matter, just the flash). You will find that you can 'see' much of the text in the book, but you

won't be able to report much of it. Moreover, although the flash lasts only microseconds, your image of the book will appear to last in the order of half a second. Sperling tested these intuitions using an ingenious experimental procedure called a partial-report procedure which is demonstrated in Figure 8.2. In this procedure an array of letters was flashed to observers for a brief period – about a twentieth of a second. The number of letters in the array was varied and the letters were arranged in rows. In Figure 8.2a, there are three rows of four digits per row. There were two report conditions. In the standard, whole-report condition, the observer simply reported as many letters as possible. In the new, partial-report condition the observer had to report only one of the rows of letters. An auditory cue presented immediately after the array and told the observer which row was to be reported: A high tone indicated the top row, a medium tone indicated the middle row, and a low tone indicated the bottom row. In the partial-report condition, Sperling estimated how many letters the observer had available by multiplying the average numbers of letters the observer was able to report from the indicated row by the number of rows. Thus, for example, if the observer could report three letters from the indicated row, the inference was that s/he must have had three letters available from each of the three rows (since s/he didn't know which row to report until after the array was physically gone) or $3 \times 3 = 9$ letters in all. Figure 8.2b shows the results of this experiment. As the number of letters in the array increased, the number of reported letters leveled out at about 4.5 for the whole-report condition – simply a replication of past results. However, in the partial-report condition, the number of letters reported continued to rise with the number of letters presented, thereby implying that the observers' first intuition was correct: They had more letters available than they were able to report in the traditional whole-report condition. In a second experiment Sperling kept the number of letters in the array constant – 12 in our example – but

varied the delay between the offset of the letter array and the auditory row-indicating cue, using a partial-report procedure. As can be seen in Figure 8.2d, the results were dramatic: As cue delay interval increased, the estimated number of letters available dropped with cue interval up to around 300 ms. The implication is that iconic memory fades away over a period of about a third of a second.

Visible persistence: the temporal integration experiment Soon after Sperling's seminal work, came a series of experiments demonstrating the essentially visual aspects of iconic memory. These experiments are best exemplified by a paradigm invented and described by Di Lollo (Di Lollo, 1980; DiLollo et al., 2001). In this paradigm, 24 dots are presented in 24 of the 25 squares of an imaginary 5 x 5 array, as shown in Figure 8.3a, and the observer's task is to report the location of the missing dot. Even when the array is shown briefly, the missing dot's location can be easily reported; however, the trick is that the 24-dot stimulus was presented as two 'frames' of 12 dots per frame, separated in time. Figure 8.3b shows the result of this experiment: When the time between the two frames was brief, the missing dot location could be reported with high probability; however, performance declined precipitously as the inter-frame interval increased up to about 150 ms.

Figure 8.2 The Partial-Report Experiment. The left panel shows the stimulus configuration: three rows of four letters per row. A high, medium, or low tone (cue) signals the observer to report the top, middle, or bottom row. The middle and right panels show data from this kind of experiment. The middle panel shows that as the number of letters in the display increases, whole-report performance levels off at 4.5 letters; however, partial-report performance continues to increase, thereby demonstrating the basic existence of a large capacity sensory memory. The right panel shows that as the delay between the array's offset and the signaling tone increases, partial report performance declines, reflecting the rapid decay of sensory memory. The bar at the far right of the right panel graph represents whole-report performance – about 4.5 letters.

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Figure 8.3 The Temporal-Integration Task. (a) The stimulus configuration. Two frames of 12 dots per frame form, when overlapping, a 5 x 5 array of dots with one dot missing. (b) Data from this kind of experiment are plotted. As the interval between the two frames increases, performance declines, demonstrating the quick decline of the visible persistence necessary to visually integrate the two frames. The interpretation was that as the first frame's iconic memory decreased over time, the first frame became less visible and could be less easily integrated with the image of the second frame. Partial report, visible persistence, and a theory that integrates them Initially, the partial-report paradigm and the temporal integration paradigm were thought to measure pretty much the same thing. It soon became clear, however, that these two aspects of iconic memory – that part that allowed information to be extracted and that part that was visible – had somewhat different characteristics (Coltheart, 1980) which meant that the two tasks were not simply two measures of the same thing.

Busey and Loftus (1994) proposed a theory designed to integrate both paradigms as well as to integrate work on sensation and perception on the one hand and work on memory on the other. The mathematics of this theory are beyond the scope of this introductory text; however the basics of it are as follows.

1. A briefly presented visual stimulus (e.g., an array of letters or an array of dots or the world lit up by a lightening flash) triggers what is called a sensory response in the nervous system. This response can be conceptualized as the magnitude of nervous activity, whose general time course is shown in Figure 8.4: Response magnitude rises with the onset of the stimulus, continues to rise for a short time following the offset of the stimulus, and then decays to zero.
2. The amount of information acquired from the stimulus (that, for example, can be used as a basis for responding in Sperling's experiments) is related to the area under the sensory-response function.
3. The visibility of the stimulus is related to the rate at which the observer is acquiring information from the stimulus. This last point, equating visibility to information acquisition rate, is not quite so odd as it might seem at first glance. Have you ever had the experience of daydreaming while driving a car and then suddenly realizing that you had not been conscious of any of the scenery that you were passing? This is tantamount to saying that your conscious awareness of the passing scenery – that is, its visibility – depends on the degree to which you were acquiring information from it: No information acquisition, no visibility.

Stimulus offset (40 milliseconds) Sensory response magnitude 40
120 200 280 Time since stimulus onset (milliseconds) Figure 8.4 Sensory Response Magnitude. A sensory response function generated by a stimulus presented for 40 milliseconds. The magnitude of the assumed neural response is plotted as a function of time since the onset of the stimulus. The area under the curve determines information acquired from the stimulus, and the height of the curve at any given point largely determines how visible the stimulus is.

INTERIM SUMMARY | Sensory memory, first explored in detail by George Sperling, has a very large capacity but decays in a very short time. Information within sensory memory that is attended to is transferred to the next memory, working memory. | Visible persistence is information that maintains a persisting, conscious, visual representation over a period of several tenths of a second. | A sensory response function is a concept that allows integration of sensory memory and visible persistence. **CRITICAL THINKING QUESTIONS** 1 In what ways are Sperling's partial-report experiment analogous to a college teacher's testing you on the material learned in a class? In what ways are the experiment and the exam process different? 2 Do you think that the partial-report experiment or the temporal-integration experiment more closely measures the contents of consciousness? Explain the reasons for your answer. **WORKING MEMORY** As noted earlier, sensory memory contains an enormous amount of quickly decaying information. Only information that is attended to is transferred from sensory memory to the next memory store. Atkinson and Shiffrin referred to this memory store as short-term memory. Experiments demonstrate that a short-term memory system exists that is separate from both the sensory stores and long-term memory (e.g., Brown, 1958; Peterson & Peterson, 1959). In this section we first discuss classic findings about how information is encoded, stored, and retrieved from short-term memory. We then discuss the contemporary view of short-term memory as a 'workspace' for performing mental computations on

information that is relevant to the task at hand so that we may perform tasks effectively. Theorists who take this view use the term working memory to refer to the short-term memory, to highlight its role in thinking rather than as simply a storage space. Encoding To encode information into working memory, we must attend to it. Since we are selective about what we attend For more Cengage Learning textbooks, visit www.cengagebrain.co.uk WORKING MEMORY to (see Chapter 5), our working memory will contain only what has been selected. This means that much of what we are exposed to never even enters working memory and, of course, will not be available for later retrieval. Indeed, many 'memory problems' are really lapses in attention. For example, if you bought some groceries and someone later asked you the color of the checkout clerk's eyes, you might be unable to answer, not because of a failure of memory but because you had not paid attention to the clerk's eyes in the first place. This phenomenon is nicely illustrated (on the next page) by a Doonesbury cartoon published some years ago. Phonological coding When information is encoded into memory, it is entered in a certain code or representation. For example, when you look up a phone number and retain it until you have dialed it, in what form do you represent the digits? Is the representation visual – a mental picture of the digits? Is it phonological – the sounds of the names of the digits? Research indicates that we can use both of these possibilities to encode information into working memory, although we favor a phonological code when we are trying to keep the information active through rehearsal – that is, by repeating an item over and over. Rehearsal is a particularly popular strategy when the information consists of verbal items such as digits, letters, or words. So in trying to remember a phone number, we are most likely to encode the number as the sounds of the digit names and to rehearse these sounds to ourselves until we have dialed the number. In a classic experiment that provided evidence for a phonological code, researchers briefly showed participants a list of six consonants (for example, RLBKSJ); when the letters were removed, they had to write all six letters in order. Although the entire procedure took only a second or two, participants occasionally made errors. When they did, the incorrect letter tended to be similar in sound to the correct one. For the list mentioned, a participant might have written RLTKSJ, replacing the B with the similar-sounding T (Conrad, 1964). This finding supports the hypothesis that the participants encoded each letter phonologically (for example, 'bee' for B), sometimes lost part of this code (only the 'ee' part of the sound remained), and then responded with a letter ('tee') that was consistent with the remaining part of the code. This hypothesis also explains why it is more difficult to recall the items in order when they are acoustically similar (for example, TBCGVE) than when they are acoustically distinct (RLTKSJ). Visual coding If need be, we can also maintain verbal items in a visual form. Experiments indicate that while we can use a visual code for verbal material, the code fades quickly. When a person must store nonverbal items (such as pictures that

278 CHAPTER 8 MEMORY are difficult to describe and therefore difficult to rehearse phonologically), the visual code becomes more important. For example, imagine the task of fitting several pieces of luggage into the back of one's car. An effective strategy might be to encode a short-term representation of each bag, and to then imagine its placement in the car to determine whether it would fit. People are quite variable in their abilities to make such mental images. While most of us can maintain some kind of visual image in working memory, a few people are able to maintain images that are almost photographic in clarity. This ability occurs mainly in children. Such children can look briefly at a For more Cengage Learning textbooks, visit www.cengagebrain.co.uk DOONESBURY ^a GARY B. TRUDEAU. REPRINTED WITH PERMISSION OF UNIVERSAL PRESS SYNDICATE. ALL RIGHTS RESERVED. picture and, when it is removed, still experience the image

before their eyes. They can maintain the image for as long as several minutes and, when questioned, provide a wealth of detail, such as the number of stripes on a cat's tail (see Figure 8.5). Such children seem to be reading the details directly from an eidetic (or photographic) image (Haber, 1969). Eidetic imagery is very rare, though. Some studies with children indicate that only about 5 percent report visual images that are long-lasting and possess sharp detail. Moreover, when the criteria for possessing true photographic imagery are made more stringent – for example,

Figure 8.5 Testing for Eidetic Images. This test picture was shown to elementary school children for 30 seconds. After the picture was removed, one boy saw in his eidetic image 'about 14' stripes in the cat's tail. The painting, by Marjorie Torrey, appears in Lewis Carroll's *Alice in Wonderland*, abridged by Josette Frank. (From *Alice in Wonderland*, abridged by Josette Frank, Random House, 1955) being able to read an imaged page of text as easily from the bottom up as from the top down – the frequency of eidetic imagery becomes minuscule, even among children (Haber, 1979). The visual code in working memory, then, is something short of a photograph. This makes complete sense when we think back about how the retina of the eye is organized (Chapter 4). The high-resolution central fovea allows detailed perception only of the central area of the scene; the periphery is progressively lower-resolution. So even if the brain were able to 'take a photograph' of a scene as perceived while the eyes were steady, the result would be a picture that, while clear and focused at the center, became progressively blurrier toward the periphery. Current conceptions of working memory The existence of both phonological and visual codes led researchers to argue that working memory consists of For more Cengage Learning textbooks, visit www.cengagebrain.co.uk WORKING MEMORY a MARKRUBRICO j DREAMSTIME.COM When you look up a phone number and retain it until you have dialed it, do you retain it visually, phonologically, or semantically? several distinct workspaces or buffers. One system (referred to as the phonological loop) is for storing and operating upon information in an acoustic code. Information in this system may be rapidly forgotten but may be maintained indefinitely through the process of rehearsal. A second is referred to as the visual-spatial sketchpad, which holds and operates upon visual or spatial information (Baddeley, 1986). For example, look at the picture that follows. Try to figure out whether each object in the left panel does or does not match each of the right-panel counterparts, that is, whether the two objects are identical or are mirror-images of one another. Most people make this determination by first making a mental image of one object, and then mentally rotating it so that it is in the same spatial orientation as the comparison object. This task illustrates many of the attributes of working memory. First, the visual information is not only being stored for the short term – it is also being actively operated upon in order to perform some ongoing realworld task. Second, the visual information is being held

280 CHAPTER 8 MEMORY Mental rotation stimuli for the short term, and will be replaced by different information as soon as the person is done with the task. Finally, note that you are aware of the information while it is present in working memory. As will be discussed later, the contents of working memory constitute much of what we are currently conscious of (some people have gone so far as to equate working memory and consciousness, e.g., Baddeley & Andrade, 2000). Various types of evidence indicate that the phonological loop and the visual-spatial sketchpad are mediated by different brain structures. For instance, Warrington and Shallice (1969) reported a patient who, following a brain injury, could repeat back only two or three consecutive digits presented to him (normal individuals can report back about seven digits). However, this same individual performed normally on visual-spatial working memory tasks such as the mental rotations

task described earlier. This pattern suggests that the patient had suffered damage to his phonological loop, but not to his visual-spatial sketchpad. Brain imaging experiments further support separate working memory components. In one experiment, on every trial participants saw a sequence of letters in which both the identity and the position of the letter varied from one item to another (see Figure 8.6). On some trials, participants had to attend only to the identity of the letters; their task was to determine whether each letter presented was identical to the one presented three back in the sequence. On other trials, participants had to attend only to the position of the letters; their task was to determine whether each letter's position was identical to the position of the letter presented three back in the sequence (see Figure 8.6). Thus, the actual stimuli were identical in all cases; what varied was whether the participants were storing verbal information (the identities of the letters) or spatial information (the positions of the letters). Presumably, the verbal information was being stored in the phonological loop and the spatial information in the visual-spatial sketchpad. On both the identity and the spatial trials, PET measures of brain activity were recorded. The results indicated that the two buffers are in different hemispheres. On trials in which participants had to store verbal information (acoustic buffer), most of the brain activity was in the left hemisphere; on trials in which participants had to store spatial information (visual-spatial buffer), most of the brain activity was in the right hemisphere. The two buffers seem to be distinct systems (Smith, Jonides, & Koeppe, 1996). This finding is not very surprising, considering the brain's tendency toward hemispheric specialization as discussed in Chapter 2. How do the phonological loop and the visual-spatial sketchpad interact with one another? Baddeley and Hitch (1974) proposed that both of these systems are controlled by another 'master' system called the executive. This system controls the other two systems by deciding what information will be encoded into them (that is, it directs attention), and what operations will be performed on that information. Because the other two systems are under the control of the executive they are sometimes referred to as 'slave systems'. Finally, Baddeley (2000) recently acknowledged the need to propose an additional component of working memory, called the episodic buffer. An important function of this subsystem is to bind or associate different aspects of a memory. For instance, the phonological loop may store a person's name, and the

visual-spatial sketchpad her face—but the episodic buffer would associate the two so that the name and face 'go together'. Storage Perhaps the most striking fact about working memory is that its capacity is very limited. For the phonological loop, the limit is seven items, give or take two (7 ± 2). Some people store as few as five items; others can retain as many as nine. It may seem strange to give such an exact number to cover all people when it is clear that individuals differ greatly in memory ability. These differences, however, are due primarily to long-term memory. For working memory, most normal adults have a capacity of 7 ± 2. This constancy has been known since the earliest days of experimental psychology. Hermann Ebbinghaus, who began the experimental study of memory in 1885, reported results showing that his own limit was seven items. Some 70 years later, George Miller (1956) was so struck by the consistency of this finding that he referred to

it as the 'magic number seven', and we now know that the limit holds in non-Western cultures as well as Western ones (Yu et al., 1985). Psychologists determined this number by showing people various sequences of unrelated items (digits, letters, or words) and asking them to recall the items in order. The items are presented rapidly, and the individual does not have time to relate them to information stored in longterm memory; hence, the number of items recalled reflects only the storage capacity of the individual's working memory. On the initial trials, participants have to recall just a few items – say, three or four digits – which they can easily do. In subsequent trials, the number of digits increases until the experimenter determines the participant's memory span – the maximum number of items (almost always between five and nine) that the participant can recall in perfect order. This task is so simple that you can easily try it yourself. The next time you come across a list of names (a directory in a business or university building, for example), read through the list once and then look away and see how many names you can recall in order. It will probably be between five and nine.

Chunking As just noted, the memory-span procedure discourages individuals from connecting the items to be remembered to information in long-term memory. When such connections are possible, performance on the memory-span task can change substantially. To illustrate this change, suppose that you were presented with the letter string SRUOYYLERECNIS. Because your memory span is 7, you would probably be unable to repeat the entire letter sequence since it contains 14 letters. If, however, you noticed that these letters spell the phrase SINCERELY YOURS in reverse order, your task would become easier. By using this knowledge, you have decreased the number of items that must be held in working memory from 14 to 2 (the 2 words). But where did this spelling knowledge come from? From long-term memory, where knowledge about words is stored. Thus, you can use long-term memory to perform what is known as chunking, or recoding new material into larger, more meaningful units and storing those units in working memory. Such units are called chunks, and the capacity of working memory is best expressed as 7 ± 2 chunks (Miller, 1956). Chunking can occur with numbers as well. The string 106614921918 is beyond our capacity, but 1066 – 1492 – 1918 is well within it or it is if you are knowledgeable about European history. The general principle is that we can boost our working memory by regrouping sequences of letters and digits into units that can be found in longterm memory (Bower & Springston, 1970).

Forgetting We may be able to hold on to seven items briefly, but in most cases they will soon be forgotten. Forgetting occurs either because the items 'decay' over time or because they are displaced by new items. Information in working memory may simply decay as time passes. We may think of the representation of an item as a trace that fades within a matter of seconds. One of the best pieces of evidence for this hypothesis is that our working memory span holds fewer words when the words take longer to say; for example, the span is less for long words such as 'harpoon' and 'cyclone' than for shorter words such as 'cat' and 'pen' (try saying the words to yourself to see the difference in duration). Presumably this effect arises because as the words are presented we say them to ourselves, and the longer it takes to do this, the more likely it is that some of the words' traces will have faded before they can be recalled (Baddeley, Thompson, & Buchanan, 1975). The other major cause of forgetting in working memory is the displacement of old items by new ones. The notion of displacement fits with the idea that working memory has a fixed capacity. Being in working memory may correspond to being in a state of activation. The more items we try to keep active, the less activation there is for any one of them. Perhaps only about seven items can be simultaneously maintained at a level of activation that permits all of them to be recalled. Once seven items are active, the activation given to a new item will be taken away from items that were presented earlier; consequently, those items may fall

below the critical level of activation needed for recall (Anderson, 1983). Retrieval Let us continue to think of the contents of working memory as being active in consciousness. Intuition suggests that access to this information is immediate. You do

282 CHAPTER 8 MEMORY not have to dig for it; it is right there. Retrieval, then, should not depend on the number of items in consciousness. But in this case intuition is wrong. Research has shown that the more items there are in working memory, the slower retrieval becomes. Most of the evidence for this comes from a type of experiment introduced by Sternberg (1966). On each trial of the experiment, a participant is shown a set of digits, called the memory list, that he or she must temporarily maintain in working memory. It is easy for the participant to do so because the memory list contains between one and six digits. The memory list is then removed from view and a probe digit is presented. The participant must decide whether the probe was on the memory list. For example, if the memory list is 3 6 1 and the probe is 6, the participant should respond 'yes'; given the same memory list and a probe of 2, the participant should respond 'no'. Participants rarely make an error on this task; what is of interest, however, is the decision time, which is the elapsed time between the onset of the probe and the participant's pressing of a 'yes' or a 'no' button. Figure 8.7 presents data from such an experiment, indicating that decision time increases directly with the length of the memory list. What is remarkable about these decision times is that they fall along a straight line. This means 'yes' responses 'no' responses 600 Decision time (milliseconds) 450 350 2 4 6 Number of items in working memory Figure 8.7 Retrieval as a Search Process. Decision times increase in direct proportion to the number of items in short-term memory. Green circles represent yes responses; purple circles, no responses. The times for both types of decision fall along a straight line. Because the decision times are so fast, they must be measured with equipment that permits accuracy in milliseconds (thousandths of a second). (Adapted from 'High Speed Scanning in Human Memory', reprinted with permission from Science, vol. 153, August 5, 1966, pp. 652-654 by S. Sternberg. Copyright © 1966 by the American Association for the Advancement of Science.) For more Cengage Learning textbooks, visit www.cengagebrain.co.uk that each additional item in working memory adds a fixed amount of time to the retrieval process – approximately 40 milliseconds, or 1/25 of a second. The same results are found when the items are letters, words, auditory tones, or pictures of people's faces (Sternberg, 1975). The most straightforward interpretation of these results is that retrieval requires a search of working memory in which the items are examined one at a time. This search presumably operates at a rate of 40 milliseconds per item, which is too fast for people to be aware of it (Sternberg, 1966). However, thinking of working memory as a state of activation leads to a different interpretation of the results. Retrieval of an item in working memory may depend on the activation of that item reaching a critical level. That is, one decides that a probe is in working memory if it is above a critical level of activation, and the more items there are in working memory, the less activation there is for any one of them (Monsell, 1979). Such activation models have been shown to accurately predict many aspects of retrieval from working memory (McElree & Doescher, 1989). Working memory and thought Working memory plays an important role in thought. When consciously trying to solve a problem, we often use working memory to store parts of the problem as well as information accessed from long-term memory that is relevant to the problem. To illustrate, consider what it takes to multiply 35 by 8 in your head. You need working memory to store the given numbers (35 and 8), the nature of the operation required (multiplication), and arithmetic facts such as $8 \times 5 = 40$ and $8 \times 3 = 24$. Not surprisingly, performance on mental arithmetic declines substantially if you have to remember simultaneously some words or digits; try doing the mental multiplication just

described while remembering the phone number 7451739 (Baddeley & Hitch, 1974). Because of its role in mental computations, researchers often conceptualize working memory as a kind of blackboard on which the mind performs computations and posts the partial results for later use (Baddeley, 1986). Other research shows that working memory is used not only in doing numerical problems but also in solving a wide range of complex problems. An example of such problems is geometric analogies, which are sometimes used in tests of intelligence (e.g., Ravens, 1965). An illustration of a geometric analogy is presented in Figure 8.8. Try to solve it; this will give you an intuitive idea of the role of working memory in problem solving. You may note that you need working memory to store (a) the similarities and differences that you observe among the forms in a row, and (b) the rules that you come up with to account for these similarities and differences and that you then use to select the correct answer. It turns out that the larger one's working memory, the better one

does on problems like these (even though there is relatively little variation among people in the capacity of their working memory). Moreover, when computers are programmed to simulate people solving problems such as the one in Figure 8.8, one of the most important determinants of how well the program does is the size of the working memory created by the programmer. There seems to be little doubt that part of the difficulty of many complex problems is the load they place on working memory (Carpenter, Just, & Shell, 1990). Working memory is also crucial for language processes like following a conversation or reading a text. When reading for understanding, often we must consciously relate new sentences to some prior material in the text. This relating of new to old seems to occur in working memory because people who have more working-memory capacity score higher than others on reading comprehension tests (Daneman & Carpenter, 1980; Just & Carpenter, 1992). Transfer from working memory to long-term memory From what we have seen so far, working memory serves two important functions: It stores material that is needed for short periods, and it serves as a work space for mental computations. Another possible function is serving as a way station to long-term memory. That is, information may reside in working memory while it is being encoded or transferred into long-term memory (Atkinson & Shiffrin, 1971a,b; Raaijmakers & Shiffrin, 1992). While there are a number of different ways to implement the transfer, one way that has been the subject of considerable research is rehearsal, the conscious repetition of information in working memory. Rehearsal apparently not only maintains the item in working memory but also can cause it to be transferred to long-term memory. Thus, the term 'maintenance rehearsal' is used to refer to active efforts to hold information in working memory; elaborative rehearsal refers to efforts to encode information in long-term memory. Some of the best evidence for the 'way-station' function of working memory comes from experiments on free recall. In a free-recall experiment, participants first see a list of perhaps 40 unrelated words that are presented one at a time. After all the words have been presented, participants must immediately recall them in any order (hence the designation 'free'). The results from such an experiment are shown in Figure 8.9. The chance of correctly recalling a word is graphed as a function of the word's position in the list. The part of the curve to the left in the graph is for the first few words presented, and the part to the right is for the last few words presented. ^a 1985, REPRINTED COURTESY OF BILL HOEST AND PARADE MAGAZINE 2 4 6 8 Figure 8.8 Illustration of a Geometric Analogy. The task is to inspect the forms in the top matrix in which the bottom right entry is missing, and to determine which of the eight alternatives given below is the missing entry. To do this, you have to look across each row and determine the rules that specify how the forms vary, and then do the same thing for each column. (P. A. Carpenter, M. A. Just, and P. Shell (1990),

“What one intelligence test measures: a theoretical account of the processing in the Raven Progressive Matrices Test,” *Psychological Review*, 97(3):404–431. Adapted by permission of the American Psychological Association.) WORKING MEMORY For more Cengage Learning textbooks, visit www.cengagebrain.co.uk

284 CHAPTER 8 MEMORY Short-term memory Long-term memory 0.8 Probability of recall 0.6 0.4 0.2 0 10 20 30 40 Position of word in list Figure 8.9 Results of a Free Recall Experiment. The probability of recall varies with an item's position in a list, with the probability being highest for the last five or so positions, next highest for the first few positions, and lowest for the intermediate positions. Recall of the last few items is based on short-term memory, whereas recall of the remaining items is based on longterm memory. (B. B. Murdock (1962) 'The Serial Position Effect in Free Recall', from *Journal of Experimental Psychology*, 64:482–488. Copyright © 1962 by the American Psychological Association. Adapted by permission.) Presumably, at the time of recall the last few words presented are still likely to be in working memory, whereas the remaining words are in long-term memory. Hence, we would expect recall of the last few words to be high because items in working memory can be retrieved easily. Figure 8.9 shows that this is indeed the case; it is called the recency effect. But recall for the first words presented is also quite good; this is called the primacy effect. Why does the primacy effect occur? This is where rehearsal enters the picture. When the first words were presented, they were entered into working memory and rehearsed. Since there was little else in working memory, they were rehearsed often and therefore were likely to be transferred to long-term memory. As more items were presented, working memory quickly filled up and the opportunity to rehearse and transfer any given item to long-term memory decreased. So only the first few items presented enjoyed the extra opportunity for transfer, which is why they were later recalled so well from longterm memory. A classic demonstration of this explanation was provided by the American psychologist, Dewey Rundus, in 1971. Rundus carried out a free-recall experiment in which subjects were required to rehearse the words they were learning, that is, they were asked to speak the words For more Cengage Learning textbooks, visit www.cengagebrain.co.uk aloud as the list was being presented. Which of the list words the subjects spoke at any moment was up to them as long as they included only list words. Rundus recorded the words as they were being spoken; thus he eventually had, for each word in each list, (1) the number of times it was rehearsed and (2) its probability of being recalled. Rundus discovered that, not surprisingly, earlier list words received more rehearsals and, as we have noted, were also recalled better. What is more important, however, is that Rundus found that the number of rehearsals was sufficient to explain the primacy effect. Consider, for instance, a word near the beginning of the list that happened to be rehearsed relatively few times. Such a word was recalled no better than a word with an equal number of rehearsals from the middle of the list. Conversely, a word from the middle of the list that, for whatever reason, happened to be rehearsed many times was remembered as well as an equally rehearsed word from the beginning of the list. Thus, the primacy effect (and, Rundus discovered, several other classic free-recall effects) were mediated by the number of rehearsals accorded a particular word. In sum, working memory is a system that can hold roughly 7 2 chunks of information in either a phonological or a visual format. Information is lost from working memory through either decay or displacement, and is retrieved from this system by a process that is sensitive to the total number of items being kept active at any given time. Lastly, working memory is used to store and process information that is needed during problem solving, and therefore is critical for thought. Division of brain labor between working memory and long-term memory It has been known for some time that working memory and long-term memory

are implemented by somewhat different brain structures. In particular, the hippocampus, a structure located near the middle of the brain beneath the cortex, is critical for long-term memory but not for working memory. Much of the relevant evidence comes from experiments with monkeys and other nonhuman species. In some experiments, one group of monkeys is first subjected to damage to the hippocampus and the surrounding cortex, and a second group is subjected to damage in a completely different region, the front of the cortex. Both groups of monkeys then have to perform a delayed-response task. On each trial, first one stimulus (such as a square) is presented and then, after a delay, a second stimulus (such as a triangle) is presented; the animal has to respond only when the second stimulus differs from the first. How well the animal performs on this task depends on the kind of brain damage it has suffered and the length of the delay between the two stimuli.

When the delay is long (15 seconds or more), animals with damage to the hippocampus perform poorly, but those with damage in the front of the cortex perform relatively normally. Because a long delay between stimuli requires long-term memory for storage of the first stimulus, these results fit with the idea that the hippocampus is critical for long-term memory. When the delay between the two stimuli is short (just a few seconds), the opposite results occur: Now animals with damage in the front of the cortex perform poorly and those with hippocampal damage perform relatively normally. Because a short delay between stimuli requires working memory for storage of the first stimulus, these results indicate that regions in the frontal cortex are involved in working memory. Hence, different regions of the brain are involved in working memory and long-term memory (Goldman-Rakic, 1987; Zola-Morgan & Squire, 1985). What evidence is there for this distinction in humans? Patients who happen to have suffered damage in certain brain regions provide an 'experiment of nature'. Specifically, some patients have suffered damage to the hippocampus and surrounding cortex, and consequently show a severe memory loss; because the hippocampus is located in the middle of the temporal lobe, these patients are said to have medial-temporal lobe amnesia. Such patients have profound difficulty remembering material for long intervals but rarely have any trouble remembering material for a few seconds. Thus, a patient with medial-temporal lobe amnesia may be unable to recognize his doctor when she enters the room – even though the patient has seen this doctor every day for years – yet will have no trouble repeating the physician's name when she is reintroduced (Milner, Corkin, & Teuber, 1968). Such a patient has a severe impairment in long-term memory but a normal working memory. Other patients, however, show the opposite problem. They cannot correctly repeat a string of even three words, yet they are relatively normal when tested on their longterm memory for words. Such patients have an impaired working memory but an intact long-term memory. And their brain damage is never in the medial temporal lobe (Shallice, 1988). Thus, for humans as well as for other mammals, working memory and long-term memory are mediated by different brain structures. Recent research using brain-scanning techniques has revealed that neurons in the prefrontal lobes, just behind the forehead, hold information for short-term use, such as a phone number that is about to be dialed. These neurons appear to act like a computer's random access memory (RAM) chips, which hold data temporarily for current use and switch quickly to other data as needed. These cells are also able to draw information from other regions of the brain and retain it as long as it is needed for a specific task (Goldman-Rakic, cited in Goleman, 1995). For more Cengage Learning textbooks, visit www.cengagebrain.co.uk LONG-TERM MEMORY INTERIM SUMMARY I Information in working memory tends to be encoded acoustically, although we can also use a visual code. I Working memory is conceptualized as being divided into an 'auditory' part, the phonological

loop and a 'visual' part, the visual-spatial sketchpad. | The auditory storage capacity is limited to 7 2 chunks. The amount of information in working memory can be increased by increasing the amount of information in each chunk, e.g., by chunking sequences of letters into meaningful units like words. | Retrieval from working memory slows down as the number of items in working memory increases. | Working memory is used in solving various kinds of problems, such as mental arithmetic, geometric analogies, and answering questions about text. | Working memory acts as a buffer from which information may be transferred to long-term memory. | Experiments with the hippocampus and surrounding brain areas support a qualitative distinction between working memory and long-term memory. CRITICAL THINKING QUESTIONS 1 Why do you think that phonological encoding is such a major part of how working memory is organized? 2 How might an increase in the size of your working memory affect your performance on a standardized test of comprehension like the SAT? Try to explain how underlying comprehension processes might be affected. LONG-TERM MEMORY Long-term memory is involved when information has to be retained for intervals as brief as a few minutes (such as a point made earlier in a conversation) or as long as a lifetime (such as an adult's childhood memories). In experiments on long-term memory, psychologists have generally studied forgetting over intervals of minutes, hours, or weeks, but a few studies have involved years or even decades. Experiments that use intervals of years often involve the recall of personal experience (called autobiographical memory) rather than the recall of laboratory materials. In what follows, studies using both kinds of material are intermixed because they seem to reflect many of the same principles.

286 CHAPTER 8 MEMORY Our discussion of long-term memory will again distinguish among the three stages of memory – encoding, storage, and retrieval – but this time there are two complications. First, unlike the situation with working memory, important interactions between encoding and retrieval occur in long-term memory. In view of these interactions, we will consider some aspects of retrieval in our discussion of encoding and present a separate discussion of interactions between encoding and retrieval. The other complication is that it is often difficult to know whether forgetting from long-term memory is due to a loss from storage or to a failure in retrieval. To deal with this problem, we will delay our discussion of storage until after we have considered retrieval so that we have a clearer idea of what constitutes good evidence for a storage loss. Encoding Encoding meaning For verbal material, the dominant long-term memory representation is neither acoustic nor visual; instead, it is based on the meanings of the items. Encoding items according to their meaning occurs even when the items are isolated words, but it is more striking when they are sentences. Several minutes after hearing a sentence, most of what you can recall or recognize is the sentence's meaning. Suppose that you heard the sentence, 'The author sent the committee a long letter'. The evidence indicates that two minutes later you would do no better than chance in telling whether you had heard that sentence or one that has the same meaning: 'A long letter was sent to the committee by the author' (Sachs, 1967). Encoding of meaning is pervasive in everyday memory situations. When people report on complex social or political situations, they may misremember many of the specifics (who said what to whom, when something was said, who else was there) yet can accurately describe the basic situation. Thus, in the Watergate scandal of the early 1970s that led to the downfall of American President Nixon, the chief government witness (John Dean) was subsequently shown to have made many mistakes about what was said in particular situations, yet his overall testimony is generally thought to accurately describe the events that occurred (Neisser, 1982). Although meaning may be the dominant way of representing verbal material in long-term memory, we sometimes code other

aspects as well. We can, for example, memorize poems and recite them word for word. In such cases we have coded not only the meaning of the poem but the exact words themselves. We can also use a phonological code in long-term memory. When you get a phone call and the other party says 'Hello', you often recognize the voice. In a case like this, you must have coded the sound of that person's voice in long-term memory. Visual impressions, tastes, and smells are also coded in long-term memory. Thus, long-term memory has a preferred code for verbal material (namely, meaning), but other codes can be used as well. Adding meaningful connections Often the items that we need to remember are meaningful but the connections between them are not. In such cases memory can be improved by creating real or artificial links between the items. For example, people who are learning to read music must remember that the five lines in printed music are referred to as EGBDF; although the symbols themselves are meaningful (they refer to notes on a keyboard), their order seems arbitrary. What many learners do is convert the symbols into the sentence 'Every Good Boy Does Fine'; the first letter of each word names each symbol, and the relationships between the words in the sentence supply meaningful connections between the symbols. These connections aid memory because they provide retrieval paths between the words: Once the word 'Good' has been retrieved, for example, there is a path or connection to 'Boy', the next word that must be recalled. One of the best ways to add connections is to elaborate on the meaning of the material while encoding it. The more deeply or elaborately one encodes the meaning, the better the resulting memory will be (Craik & Tulving, 1975). Thus, if you have to remember a point made in a textbook, you will recall it better if you concentrate on its meaning rather than on the exact words. And the more deeply and thoroughly you expand on its meaning, the better you will recall it. An experiment by Bradshaw and Anderson (1982) illustrates some of these points. Participants read facts about famous people that they would later have to recall, such as 'At a critical point in his life, Mozart made a journey from Munich to Paris'. Some facts were elaborated according to either their causes or their consequences, as in 'Mozart wanted to leave Munich to avoid a romantic entanglement'. Other facts were presented alone. Later the participants were tested on their memory of just the facts (not the elaborations). Participants recalled more facts that had been given elaborations than facts that had been presented alone. Presumably, in adding the cause (or consequence) to their memory representation, they set up a retrieval path from the cause to the target fact in the following manner: I Mozart journeyed from Munich to Paris. I Mozart wanted to avoid a romantic entanglement in Munich. At the time of recall, participants could either retrieve the target fact directly or retrieve it indirectly by following the path from its cause. Even if they forgot the target fact, they could infer it if they retrieved the cause. Results like these establish an intimate connection between understanding and memory. The better we understand some material, the more connections we see

^a SHACKMAN / MONKMEYER PRESS When we forget information in long-term memory, it doesn't mean that the information itself is lost. We may be able to retrieve the information if something reminds us of it. This is one reason that families maintain photograph albums. between its parts. Because these connections can serve as retrieval links, the better we understand items and the more we remember. Retrieval Many cases of forgetting from long-term memory result from loss of access to the information rather than from loss of the information itself. That is, poor memory often reflects a retrieval failure rather than a storage failure. (Note that this is unlike working memory, in which forgetting is a result of decay or displacement and retrieval is thought to be relatively error free.) Trying to retrieve an item from long-term memory is like trying to find a book in a large

library. Failure to find the book does not necessarily mean that it is not there; you may be looking in the wrong place, or the book may simply be misfiled. Evidence for retrieval failures Our everyday experience provides considerable evidence for retrieval failures. At some point all of us have been unable to recall a fact or experience, only to have it come to mind later. How many times have you taken an exam and not been able to recall a specific name, only to remember it later? Another example is the 'tip-of-the-tongue' phenomenon, in which a particular word or name lies tantalizingly outside our ability to recall it (Brown & McNeill, 1966). We may feel quite tormented until a search of memory (dredging up and then discarding words that are close but not quite right) finally retrieves the correct word. A more striking example of retrieval failure occurs when a person undergoing psychotherapy retrieves a memory that had previously been forgotten. Although we lack firm evidence for such occurrences, they suggest that some seemingly forgotten memories are not lost but merely difficult to get at. For more Cengage Learning textbooks, visit www.cengagebrain.co.uk

LONG-TERM MEMORY For stronger evidence that retrieval failures can cause forgetting, consider the following experiment. Participants were asked to memorize a long list of words. Some of the words were names of animals, such as dog, cat, horse; some were names of fruit, such as apple, orange, pear; some were names of furniture; and so on (see Table 8.1). At the time of recall, the participants were divided into two groups. One group was supplied with retrieval cues such as 'animal', 'fruit', and so on; the other group, the control group, was not. The group that was given the retrieval cues recalled more words than the control group. In a subsequent test, when both groups were given the retrieval cues, they recalled the same number of words. Hence, the initial difference in recall between the two groups must have been due to retrieval failures.

Table 8.1 Examples from a study of retrieval failures

Participants who were not given the retrieval cues recalled fewer words from the memorized list than other participants who were given the cues. This finding shows that problems at the retrieval stage of long-term memory are responsible for some memory failures. (E. Tulving and Z. Pearlstone (1976) 'Availability and Accessibility', from <i>Journal of Memory and Language</i> , 5:381–391. Reprinted by permission of Academic Press.)	List to be memorized
dog	cotton
oil	cat
wool	gas
horse	silk
coal	cow
rayon	wood
apple	blue
doctor	orange
red	lawyer
pear	green
teacher	banana
yellow	dentist
chair	knife
football	table
spoon	baseball
bed	fork
basketball	sofa
pan	tennis
knife	hammer
shirt	gun
saw	socks
rifle	nails
pants	bomb
screwdriver	shoes
Retrieval cues	animals
cloth	fuels
fruit	color
professions	furniture
utensils	sports
weapons	tools
clothing	

288 CHAPTER 8 MEMORY In sum, the better the retrieval cues available, the better our memory. This principle explains why we usually do better on a recognition test of memory than on a recall test. In a recognition test, we are asked whether we have seen a particular item before (for example, 'Was Bessie Smith one of the people you met at the wedding?'). The test item itself is an excellent retrieval cue for our memory of that item. In contrast, in a recall test, we have to produce the memorized items using minimal retrieval cues (for example, 'Recall the name of the woman you met at the party'). Since the retrieval cues in a recognition test are generally more useful than those in a recall test, performance is usually better on recognition tests (such as multiple-choice exams) than on recall tests (such as essay exams) (Tulving, 1974).

Interference Among the factors that can impair retrieval, the most important is interference. If we associate different items with the same cue, when we try to use that cue to retrieve one of the items (the target item), the other items may become active and interfere with our recovery of the target. For example, if your friend Dan moves and you finally learn his new phone number, you will find it difficult to retrieve the old number. Why? Because you are using the cue 'Dan's phone number' to retrieve the old number,

but instead this cue activates the new number, which interferes with recovery of the old one. (This is referred to as retroactive interference.) Or suppose that your reserved space in a parking garage, which you have used for a year, is changed. At first you may find it difficult to retrieve your new parking location from memory. Why? Because you are trying to learn to associate your new location with the cue 'my parking place', but this cue retrieves the old location, which interferes with the learning of the new one (proactive interference). In both examples, the power of retrieval cues ('Dan's phone number' or 'my parking place') to activate particular target items decreases with the number of other items associated with those cues. The more items are associated with a cue, the more overloaded it becomes and the less effective it is in aiding retrieval. Interference can operate at various levels, including the level of whole facts. In one experiment, participants first learned to associate various facts with the names of professions. For example, they learned the following associations: The banker: (1) was asked to address the crowd, (2) broke the bottle, and (3) did not delay the trip. The lawyer: (1) realized that the seam was split, and (2) painted an old barn. For more Cengage Learning textbooks, visit www.cengagebrain.co.uk

Mean percent savings

Retention interval	1/3 hr	1 hr	8 hr	24 hr	days	days	days
Figure 8.10	60	20	10	5	3	2	1

Forgetting as a Function of Time. A forgetting curve graphs the decline in recall as a function of time. This graph was one of the first forgetting graphs ever, reported by Ebbinghaus (1885). The occupational names 'banker' and 'lawyer' were the retrieval cues. Since 'banker' was associated with three facts and 'lawyer' was associated with just two, 'banker' should have been less useful than 'lawyer' in retrieving any of its associated facts ('banker' was the more overloaded cue). When participants were later given a recognition test, they did take longer to recognize any one of the facts learned about the banker than any one of those learned about the lawyer. In this study, then, interference slowed the speed of retrieval. Many other experiments show that interference can lead to a complete retrieval failure if the target items are weak or the interference is strong (Anderson, 1983). Indeed, it has long been thought that interference is a major reason why forgetting from long-term memory increases with time: The relevant retrieval cues become more and more overloaded with time (see Figure 8.10).

Models of retrieval In attempting to explain interference effects, researchers have developed a variety of models of retrieval. As with retrieval from short-term memory, some models of long-term-memory retrieval are based on a search process whereas others are based on an activation process. The interference effects in the banker-lawyer experiment fit nicely with the idea that retrieval from long-term memory may be thought of as a search process (e.g., Raaijmakers & Shiffrin, 1981). To illustrate, consider how the sentence 'The banker broke the bottle' might be recognized (see Figure 8.11). The term 'banker' accesses its representation in memory, which localizes the search to the relevant part of long-term memory. There, three paths need to be searched to verify that 'broke the bottle' was one of the facts learned about the banker. In contrast, if the test sentence is 'The lawyer painted an old barn', there are only two paths to be searched. Since the

duration of a search increases with the number of paths to be considered, retrieval will be slower for the 'banker' sentence than for the 'lawyer' one. An alternative way to think about the retrieval process is in terms of activation. When trying to recognize 'The banker broke the bottle', for example, the participant activates the representation for 'banker' and the activation then spreads simultaneously along the three paths emanating from 'banker' (see Figure 8.11). When sufficient activation reaches 'broke the bottle', the sentence can be recognized. Interference arises because the activation from the banker representation must be subdivided among the paths emanating from it. Hence, the more facts associated with 'banker', the thinner the activation will be on each

path and the longer it will take for sufficient activation to reach any particular fact. Thus, thinking of retrieval in terms of spreading activation can also account for why interference slows retrieval (Anderson, 1983). Forgetting: loss of information from storage The fact that some forgetting is due to retrieval failures does not imply that all forgetting is. It seems most unlikely that everything we ever learned is still there in memory waiting for the right retrieval cue. Some information is almost certainly forgotten, that is, lost from storage (Loftus & Loftus, 1980). Some evidence of storage loss comes from people who receive electroconvulsive therapy to alleviate severe depression (a mild electric current applied to the brain produces a brief epileptic-like seizure and momentary unconsciousness; see Chapter 16). In such cases the patient loses some memory for events that occurred in the months just prior to the shock, but not for earlier events (Squire & Fox, 1980). These memory losses are unlikely to be due to retrieval failures because if the shock disrupted retrieval, all memories should be affected, not just the recent ones. More likely, the shock disrupts storage processes that consolidate new memories over a period of months or longer, and information that is not consolidated is lost from storage. Most research on storage in long-term memory is done at the biological level. Researchers have made substantial progress in determining the neuroanatomical bases of consolidation. It appears that the critical brain structures involved are the hippocampus and the cortex surrounding the hippocampus (which includes the entorhinal, perirhinal, and parahippocampal cortices; they are involved in the exchange of information between the hippocampus and much of the cerebral cortex). The hippocampus's role in consolidation seems to be that of a cross-referencing system, linking together aspects of a particular memory that are stored in separate parts of the brain (Squire, 1992). While a global memory loss in humans usually occurs only when the surrounding cortex as well as the 'The banker broke the bottle' Realized the seam was split Broke the bottle Did not delay the trip Asked to address the crowd BANKER 'The lawyer painted an old barn' Painted an old barn LAWYER Figure 8.11 Retrieval as a Search Process Versus an Activation Process. When the sentence 'The banker broke the bottle' is presented, the term banker accesses the banker representation in long-term memory. Once at this representation, there are three paths to be searched. When the sentence 'The lawyer painted an old barn' is presented, lawyer accesses the lawyer representation, from which there are two paths to be searched. Alternatively, the term banker may activate the banker representation, and this activation then spreads simultaneously along the three paths (and similarly for the 'lawyer' example). LONG-TERM MEMORY For more Cengage Learning textbooks, visit www.cengagebrain.co.uk

290 CHAPTER 8 MEMORY hippocampus is impaired, damage to the hippocampus alone can result in severe memory disturbance. This fact was demonstrated by a study that started with an analysis of a particular patient's memory problems (due to complications from coronary bypass surgery) and ended with a detailed autopsy of his brain after his death; the autopsy revealed that the hippocampus was the only brain structure that was damaged (Zola-Morgan, Squire, & Amaral, 1989). A study using monkeys provides the best evidence we have that the function of the hippocampus is to consolidate relatively new memories. A group of experimental monkeys learned to discriminate between items in 100 pairs of objects. For each pair, there was food under one object, which the monkey got only if it chose that object. Since all the objects differed, the monkeys essentially learned 100 different problems. Twenty of the problems were learned 16 weeks before the researchers removed the monkeys' hippocampus; additional sets of 20 problems were learned either 12, 8, 4, or 2 weeks before the hippocampal surgery. Two weeks after the surgery, the researchers tested the monkeys' memory with a single trial of each of the 100 pairs.

The key finding was that the experimental monkeys remembered discriminations that they had learned 8, 12, or 16 weeks before surgery as well as normal control monkeys did, but remembered the discriminations learned 2 or 4 weeks before surgery less well than the control monkeys did. Moreover, the experimental monkeys actually remembered less about the discriminations learned 2 to 4 weeks before surgery than about the discriminations learned earlier. These results suggest that memories need to be processed by the hippocampus for a period of a few weeks, for it is only during this period that memory is impaired by removal of the hippocampus. Permanent long-term memory storage is almost certainly localized in the cortex, particularly in the regions where sensory information is interpreted (Squire, 1992; Zola-Morgan & Squire, 1990).

Interactions between encoding and retrieval In describing the encoding stage, we noted that operations carried out during encoding, such as elaboration, make retrieval easier. Two other encoding factors also increase the chances of successful retrieval: (a) organizing the information at the time of encoding and (b) ensuring that the context in which information is encoded is similar to that in which it will be retrieved.

Organization The more we organize the material we encode, the easier it is to retrieve. Suppose that you were at a conference at which you met various professionals – doctors, lawyers, and journalists. When you later try to recall their names, you will do better if you initially organize the information by profession. For more Cengage Learning textbooks, visit www.cengagebrain.co.uk by profession. Then you can ask yourself, ‘Who were the doctors I met? Who were the lawyers?’ and so forth. A list of names or words is far easier to recall when we encode the information into categories and then retrieve it on a category-by-category basis (e.g., Bower, Clark, Winzenz, & Lesgold, 1969).

Context It is easier to retrieve a particular fact or episode if you are in the same context in which you encoded it (Estes, 1972). For example, it is a good bet that your ability to retrieve the names of your classmates in the first and second grades would improve if you were to walk through the corridors of your elementary school. Similarly, your ability to retrieve an emotional moment with a close friend – for example, an argument with her in a restaurant – would be greater if you were back in the place where the incident occurred. This may explain why we are sometimes overcome with a torrent of memories when we visit a place where we once lived. The context in which an event was encoded is one of the most powerful retrieval cues (see Figure 8.12). Context is not always external to the individual. It can include what is happening inside us when we encode information – that is, our internal state. For example, individuals who learned a list of words while under the influence of marijuana recalled more of the words when tested in the same drug-induced state than when tested in a nondrugged state, and individuals who learned the list in a nondrugged state recalled more words when tested in a nondrugged state than when tested in a drug-induced state (Eich, 1980). Such cases are referred to as **state-dependent learning** because memory is partly dependent on the internal state prevailing during learning. It is thought that feelings evoked by the altered state serve as cues for retrieving information encoded while in that state. The evidence for this phenomenon is controversial, but it does suggest that memory does improve when our internal state during retrieval matches our internal state during encoding (Eich, 1980).

Emotional factors in forgetting So far we have treated memory as if it were entirely separate from emotion. But don’t we sometimes remember or forget material because of its emotional content? There has been a great deal of research on this question. The results suggest that emotion can influence long-term memory in five distinct ways: rehearsal, flashbulb memories, retrieval interference via anxiety, context effects, and repression.

Rehearsal The simplest idea is that we tend to think about emotionally charged situations, negative as well as positive,

292 CHAPTER 8 MEMORY learned of an emotionally charged, significant event. An example is the explosion of the space shuttle Challenger in 1986, which was witnessed by millions of people on television. Many people in their twenties remember exactly where they were when they learned of the Challenger disaster and exactly who told them about it, even though these are the kinds of details that we usually forget quickly. Americans age 30 or older may have flashbulb memories of the assassination attempt on Ronald Reagan in 1981, while those age 40 or older may have such memories of the assassinations of John F. Kennedy and Martin Luther King, Jr., in the 1960s. There is a published report indicating that a century ago Americans had flashbulb memories of the assassination of Abraham Lincoln. When Colegrove (1899) interviewed 179 people, 127 of them were able to give full particulars as to where they were and what they were doing when they heard of Lincoln's assassination. The problem with early studies of flashbulb memories, such as Colegrove's, is that there was no way of assessing whether they were correct. One man, for example, described detailed memories of a powerful 1960 earthquake in Chile, recalling being woken up early in the morning by the violent shaking of his house and noticing, among other things, that his grandfather clock had stopped at 6:00 a.m. sharp. Many years later, he discovered that the earthquake had actually taken place at 2:11 p.m.: Although the earthquake was certainly real, his vivid 'flashbulb' memories of its taking place in the morning were not. Later we discuss the reconstructive processes that lead to such vivid, but incorrect memories. For the moment, it is important to point out that when flashbulb memories are carefully studied in conjunction with a record of what actually happened, flashbulb memories turn out to be susceptible to decay and interference just like other kinds of memories (e.g., Curci, Oliver, Finkenauer, & Gisle, 2001; Neisser & Harsch, 1993; Schmolck, Buffalo, & Squire, 2000; Sierra & Berrios, 2000).

Retrieval interference via anxiety There are also cases in which negative emotions hinder retrieval, which brings us to the third way emotion can affect memory. An experience that many students have at one time or another illustrates this process: You are taking an exam about which you are not very confident. You can barely understand the initial question, let alone answer it. Signs of panic appear. Although the second question really isn't hard, the anxiety triggered by the previous question spreads to this one. By the time you look at the third question, it wouldn't matter whether it only asked for your phone number. There's no way you can answer it. You're in a complete panic. For more Cengage Learning textbooks, visit www.cengagebrain.co.uk

What is happening to memory here? Failure to deal with the first question produced anxiety. Anxiety is often accompanied by extraneous thoughts, such as 'I'm going to fail' or 'Everybody will think I'm stupid'. These thoughts fill our consciousness and interfere with attempts to retrieve information that is relevant to the question; this may be why memory fails. According to this view, anxiety does not directly cause memory failure; rather, it causes, or is associated with, extraneous thoughts, and these thoughts cause memory failure by interfering with retrieval (Holmes, 1974).

Context effects Emotion may also affect memory through a context effect. As noted earlier, memory is best when the context at the time of retrieval matches that at the time of encoding. Since our emotional state during learning is part of the context, if the material we are learning makes us feel sad, perhaps we can best retrieve that material when we feel sad again. Experimenters have demonstrated such an emotional-context effect. Participants agreed to keep diaries for a week, recording every emotional incident that occurred and noting whether it was pleasant or unpleasant. One week after they handed in their diaries, the participants returned to the laboratory and were hypnotized. Half the participants were put in a pleasant mood and the other half in an unpleasant mood. All were asked to recall the incidents recorded in their diaries. For participants in a pleasant mood, most of the incidents they recalled had been rated as pleasant at the time that they were experienced; for

participants in an unpleasant mood at retrieval, most of the incidents recalled had been rated as unpleasant at the time that they were experienced. As expected, recall was best when the dominant emotion during retrieval matched that during encoding (Bower, 1981). Repression Thus far, all of the means by which emotions can influence memory rely on principles already discussed – namely, rehearsal, interference, and context effects. Another view of emotion and memory, Freud’s theory of the unconscious, brings up new principles. Freud proposed that some emotional experiences in childhood are so traumatic that allowing them to enter consciousness many years later would cause the individual to be totally overwhelmed by anxiety. Such traumatic experiences are said to be repressed, or stored in the unconscious, and they can be retrieved only when some of the emotion associated with them is defused. Repression, therefore, represents the ultimate retrieval failure: Access to the target memories is actively blocked. This notion of active blocking makes the repression hypothesis qualitatively different from the ideas about forgetting discussed earlier. (For a discussion of Freud’s theory, see Chapter 13.)

Repression is such a striking phenomenon that we would of course like to study it in the laboratory, but it has proved difficult to do this. To induce true repression in the laboratory, the experimenter must cause the participant to experience something extremely traumatic, but this obviously would be unethical. The studies that have been done have exposed participants to mildly upsetting experiences, and the results have been mixed (Baddeley, 1990; Erdelyi, 1985). In sum, long-term memory is a system that can hold information for days, years, or decades, typically in a code based on meaning, although other codes are possible. Retrieval of information from this system is sensitive to interference; many apparent ‘storage losses’ are really retrieval failures. Storage in this system involves consolidation, a process that is mediated by the hippocampal system. Many aspects of long-term memory can be influenced by emotion; such influences may reflect selective rehearsal, retrieval interference, the effects of context, or two special mechanisms: flashbulb memories and repression.

INTERIM SUMMARY I Information in long-term memory is usually encoded according to its meaning. I Forgetting in long-term memory is due to retrieval failures (the information is there but cannot be found) and to interference by new information. I Some forgetting from long-term memory is due to a loss from storage, particularly when there is a disruption of the processes that consolidate new memories. The biological locus of consolidation includes the hippocampus and surrounding cortex. Recent research suggests that consolidation takes a few weeks to be completed. I Retrieval failures in long-term memory are less likely when the items are organized during encoding and when the context at the time of retrieval is similar to the context at the time of encoding. I Retrieval processes can also be disrupted by emotional factors.

CRITICAL THINKING QUESTION 1 We reviewed various proposals about how emotion affects explicit long-term memory. Some of these proposals imply that emotion helps memory, whereas others suggest that emotion hurts memory. How can you reconcile these apparent differences? For more Cengage Learning textbooks, visit www.cengagebrain.co.uk

IMPLICIT MEMORY IMPLICIT MEMORY Thus far, we have been concerned mainly with situations in which people remember personal facts. In such cases memory is a matter of consciously recollecting the past, and is said to be expressed explicitly. But there seems to be another kind of memory, one that is often manifested in skills and shows up as an improvement in the performance of some perceptual, motor, or cognitive task without conscious recollection of the experiences that led to the improvement. For example, with practice we can steadily improve our ability to recognize words in a foreign language, but at the moment that we are recognizing a word, and thereby demonstrating our skill, we need not have any conscious recollection of the lessons that led to our improvement. In such cases, memory is

expressed implicitly (Schacter, 1989). Memory in amnesia Much of what is known about implicit memory has been learned from people who suffer amnesia, or partial loss of memory. Amnesia may result from very different causes, including accidental injuries to the brain, strokes, encephalitis, alcoholism, electroconvulsive shock, and surgical procedures (for example, removal of the hippocampus to reduce epilepsy). Whatever its cause, the primary symptom of amnesia is a profound inability to remember day-to-day events and, hence, to acquire new factual information; this is referred to as anterograde amnesia, and it can be extensive. There is an intensively studied patient, identified as N.A., who is unable to participate in a normal conversation because at the least distraction he loses his train of thought. Another patient, identified as H.M., reads the same magazines over and over and continually needs to be reintroduced to doctors who have been treating him for decades. H.M. is the most famous of the brain-damaged patients whose memory functioning has been studied extensively (Milner, 1970; Squire, 1992). At the age of 27, H.M., who suffered from severe epilepsy, underwent surgery to remove portions of the temporal lobe and limbic system on both sides of his brain. The surgery left him unable to form new memories, although he could remember events that had occurred prior to the surgery. H.M. can retain new information as long as he focuses on it, but as soon as he is distracted he forgets the information, and he is unable to recall it later. On one occasion, for example, he kept the number 584 in mind for 15 minutes, using the following mnemonic system: '5, 8, 4 add to 17. You remember 8, subtract from 17 and it leaves 9. Divide 9 by half and you get 5 and 4, and there you are – 584' (quoted in Milner, 1970). A few minutes later, however, H.M.'s attention shifted and he could no

294 CHAPTER 8 MEMORY ^a ISTOCKPHOTO.COM/LAURA EISENBERG Memory for skills such as tying one's shoelaces is referred to as implicit memory. longer remember either the number or his method for remembering it. A secondary symptom of amnesia is inability to remember events that occurred prior to the injury or disease. The extent of such retrograde amnesia varies from one patient to another. Aside from retrograde and anterograde memory losses, the typical amnesiac appears relatively normal: He or she has a normal vocabulary, the usual knowledge about the world (at least before the onset of the amnesia), and generally no loss of intelligence. Skills and priming A striking aspect of amnesia is that not all kinds of memory are disrupted. Thus, while amnesiacs generally are unable to either remember old facts about their lives or learn new ones, they have no difficulty remembering and learning perceptual and motor skills. This suggests that there is a different memory for facts than for skills. More generally, it suggests that explicit and implicit memory (which encode facts and skills, respectively) are different systems. For more Cengage Learning textbooks, visit www.cengagebrain.co.uk The skills that are preserved in amnesia include motor skills, such as tying one's shoelaces or riding a bike, and perceptual skills, such as normal reading or reading words that are projected into a mirror (and hence reversed). Consider the ability of reading mirror-reversed words. To do this well takes a bit of practice (try holding this book in front of a mirror and reading it). Amnesiacs improve with practice at the same rate as normal participants, although they may have no memory of having participated in earlier practice sessions (Cohen & Squire, 1980). They show normal memory for the skill but virtually no memory for the learning episodes that developed it (the latter being facts). A similar pattern emerges in situations in which prior exposure to a stimulus facilitates or primes later processing of that stimulus. This pattern is illustrated in the experiment outlined in Table 8.2. In Stage 1 of the experiment, amnesiac and normal participants were given a list of words to study. In Stage 2, stems of words on the list and stems of words not on the list were presented, and the participants tried to complete them (see Table 8.2). The normal participants performed as expected,

completing more stems when they were drawn from words on the list than when they were drawn from words not on the list. This difference is referred to as priming because the words presented in Stage 1 facilitated or primed performance on the stem completion problems presented in Stage 2. Significantly, amnesiacs also completed more stems in Stage 2 when they were drawn from words on Table 8.2 Procedure for an experiment to study implicit memory in amnesia (Reprinted from *Neuropsychologia*, Vol. 16. pp. 169–172 by W. K. Warrington and L. Weiskrantz, 'Further Analysis of the Proper Learning Effect in Amnesiac Patients'. Copyright © 1978, with permission from Elsevier Science, Ltd.)

Stage	Task	Words	Completion
Stage 1	Example	Present list of words for study	MOTEL
Stage 2	Present stems of list words and nonlist words for completion.	Number of list words completed minus number of nonlist words completed	$\frac{1}{4}$ Priming
Stage 3	Present original list of words plus new words for recognition	MOTEL STAND	

the list than when they were drawn from words not on the list. In fact, the degree of priming for amnesiacs was exactly the same as for normals. This finding indicates that when memory is manifested implicitly, as in priming, amnesiacs perform normally. In Stage 3 of the experiment, the original words were presented again along with some novel words, and participants had to recognize which words had appeared on the list. Now amnesiacs remembered far fewer words than normals. Thus, when memory is tested explicitly, as in recognition, amnesiacs perform far below normals. There is an interesting variation of the preceding study that further strengthens its conclusion. Suppose that in Stage 2 participants are instructed that they will perform better on the stem-completion task if they try to think of the words presented earlier. This instruction makes stem completion into an explicit memory task (because conscious recollection is being emphasized). Now amnesiacs show substantially less priming than normal participants (Graf & Mandler, 1984).

Childhood amnesia

One of the most striking aspects of human memory is that everyone suffers from a particular kind of amnesia: Virtually no one can recall events from the first years of life, even though this is the time when experience is at its richest. This curious phenomenon was first discussed by Freud (1905), who called it childhood amnesia. Freud discovered the phenomenon by observing that his patients were generally unable to recall events from their first three to five years of life. At first you might think that there is nothing unusual about this, because memory for events declines with time, and for adults there has been a lot of intervening time since early childhood. But childhood amnesia cannot be reduced to normal forgetting. Most 30-year-olds can recall a good deal about their high school years, but it is a rare 18-year-old who can tell you anything about his or her third year of life; yet the time interval – about 15 years – is roughly the same in each case. In some studies, people have been asked to recall and date their childhood memories. For most people, their first memory is of something that occurred when they were age 3 or older; a few individuals will report memories prior to the age of 1. A problem with these reports, however, is that we can never be sure that the 'remembered' event actually occurred (the person may have reconstructed what he or she thought happened). This problem was overcome in an experiment in which participants were asked a total of 20 questions about a childhood event that was known to have occurred – the birth of a younger sibling – the details of which could be verified by another person. The questions asked of each participant dealt with events that occurred when the

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IMPLICIT MEMORY

15 Questions answered 5 1–3 3–5 5–7 7–9 9+ Age of subject when sibling was born

Figure 8.13 Recall of an Early Memory. In an experiment on childhood amnesia, college-age individuals were asked 20 questions about the events surrounding the birth of a younger sibling. The average number of questions answered is plotted as a function

of the individual's age when the sibling was born. If the birth occurred before the fourth year of life, no individual could recall a thing about it. If the birth occurred after that, recall increased with age at the time of the event. (After Sheingold & Tenney, 1982) mother left to go to the hospital (for example, 'What time of day did she leave?'), when the mother was in the hospital ('Did you visit her?'), and when the mother and infant returned home ('What time of day did they come home?'). The participants were college students, and their ages at the time that their siblings were born varied from 1 to 17 years. The results are shown in Figure 8.13. The number of questions answered is plotted as a function of the participant's age when the sibling was born. If the sibling was born before the participant was 3 years old, the person could not recall a thing about it. If the birth occurred after that, recall increased with age at the time of the event. These results suggest almost total amnesia for the first three years of life. More recent research, however, suggests that such recall may be improved if more cues are given and the cues are more specific (Fivush & Hamond, 1991). Still, the bulk of the evidence indicates that we should be skeptical about reports of memory from the first few years of life. What causes childhood amnesia? A generally accepted explanation is that childhood amnesia is due to a massive difference between how young children encode experience and how adults organize their memories. Adults structure their memories in terms of categories and schemas ('She's that kind of person', 'It's that kind of situation'), while young children encode their experiences without embellishing them or connecting them to related events. Once a child begins to form associations between events and to

296 CHAPTER 8 MEMORY categorize those events, early experiences become lost (Schachtel, 1982). What causes the shift from early childhood to adult forms of memory? One factor is biological development. The hippocampus, which is known to be involved in consolidating memories, is not mature until roughly a year or two after birth. Therefore, events that take place in the first two years of life cannot be sufficiently consolidated and consequently cannot be recalled later. Other causes of the shift to adult memory are better understood at the psychological level. These include cognitive factors, particularly the development of language and the beginning of schooling. Both language and the kind of thinking emphasized in school provide new ways of organizing experiences, ways that may be incompatible with the way the young child encodes experiences. Interestingly, language development reaches an early peak at age 3, while schooling often begins at age 5; and the age span from 3 to 5 is the time when childhood amnesia seems to end. Conceptual implicit memory There is substantial evidence suggesting that in addition to skills and words, concepts may be implicitly stored and unconsciously activated. For instance, if a person is presented a word (e.g. aubergine) and asked to write down words that come to mind, and is later asked to name the vegetables contained in ratatouille, it is more likely that the person will include aubergine in her answer even if she fails to consciously remember the previous presentation (e.g., Blaxton, 1989). The notion of conceptual implicit memory plays an important role in most modern theories of prejudice. The idea is that even a well-intentioned person may store negative implicit conceptual information about a social group based on social experiences such as media presentations. This may lead to prejudiced behaviors in situations where those implicit memories are automatically activated. For example, consider a simple experiment where participants read word pairs as quickly as possible and then press a button to receive the next word pair. Even Caucasian American college students who claim to have positive attitudes towards African Americans are likely to respond more quickly to the word pair black-lazy than to the pair black-smart (e.g., Kawakami & Dovidio, 2001). A variety of memory systems On the basis of work with various brain-damaged patients, researchers have proposed that both explicit and implicit memory

come in various forms. One such proposal is presented in the nearby Concept Review Table. The basic distinction is between explicit and implicit memory. (Recall that explicit memory involves For more Cengage Learning textbooks, visit www.cengagebrain.co.uk CONCEPT REVIEW TABLE

Proposed classification of memory stores Squire et al. (1990) propose that there are several different memory systems. The basic distinction is between explicit and implicit memory (which they refer to as declarative and nondeclarative, respectively). Explicit (Declarative) memory

Implicit (Nondeclarative) memory Episodic Skills Semantic Priming Conditioning Nonassociative

consciously recollecting the past, while implicit memory shows up as improved performance of a skill without conscious recollection of the lessons that led to it.) With regard to implicit memory, a further distinction is made between perceptual-motor skills, such as reading mirror-reversed words, and priming, as occurs in wordstem completions. The reason for assuming that skills and priming may involve different memory stores is that there are patients with brain damage (individuals in the early stages of Alzheimer's disease) who are able to learn motor skills but show less priming than normal. In contrast, there are other brain-damaged patients (individuals with Huntington's disease) who show normal priming but have difficulty learning new motor skills (Schacter, 1989). The concept review table also distinguishes between two kinds of explicit memory, which are referred to as episodic and semantic. Episodic facts refer to personal episodes and semantic facts to general truths. To illustrate, your memory of your high-school graduation is an episodic fact, and so is your memory for what you had for dinner last night. In each of these cases, the episode is encoded with respect to you, the individual (your graduation, your dinner, and so on), and often with respect to a specific time and place as well. In contrast, semantic facts, such as your memory or knowledge that the word 'bachelor' means an unmarried man and that September has 30 days, is encoded in relation to other knowledge rather than in relation to yourself, and there is no coding of time and place (Tulving, 1985). This distinction between semantic and episodic memory fits with the fact that although amnesiacs have severe difficulty remembering personal episodes, they seem relatively normal in their general knowledge.

CUTTING EDGE RESEARCH Brain states during experiencing and remembering One of the oldest questions in memory research is: How are memories represented in the brain? One of the best known research studies addressing this issue was carried out at McGill University in Montreal by the physician, Wilder Penfield in the 1950s (described, for example, in Penfield and Roberts, 1963). Penfield worked with epileptic patients who, during brain surgery, remained conscious and thus could relate their experiences (this is possible because there aren't pain receptors in the part of the brain being operated on). Penfield reported that – astonishingly – when particular regions of the brain were electrically stimulated, patients reported vividly 'reliving' previous experiences. This was long taken as evidence that memories were stored in a faithful, videotape-like manner, somewhere in the brain, waiting only for the right stimulus to spring back into consciousness. Eventually, however, cracks began to appear in this interpretation of Penfield's dramatic findings. Elizabeth and Geoffrey Loftus (1980) for instance, pointed out that many of the 'relived' experiences entailed patients who watched themselves from some vantage point other than their own eyes, e.g., a woman who watched herself giving birth to her child from across the room. This suggests that the memories elicited by Penfield's electrodes were memories constructed from past experience rather than literal reproductions of original long-ago experiences. Very recently, however, the Israeli neuroscientist, Hagar Gelbard-Sagiv, along with several other Israeli and American colleagues, Roy Mukamel, Michael Harel, Fafael Malach, and Itzhak Fried (2008) presented results that, at least for memories of relatively short-term experiences, the brain may

represent the memory for the experience in somewhat the same way as it represented the experience itself as it was ongoing. Like Penfield, they had access to the brain of epileptic patients undergoing surgery. Unlike Penfield, they did not stimulate the brain, but rather they recorded from single neurons in the medial temporal lobe – particularly the hippocampus – brain sections that respond to complex stimuli, that is, real-world experiences and translate them into eventual memories. These researchers presented their patients with 5–10 second film clips of familiar people, places, events, or movies such as: Niagara Falls, a tsunami, The Matrix, Osama Bin Laden, the Eiffel Tower, and Harry Potter, just to name a few. They recorded from a number of single neurons during these filmviewing sessions, and kept track of which neurons responded most vigorously to which particular parts of which particular Implicit memory in normal individuals

Studies using normal individuals also suggest that there are separate systems for explicit and implicit memories. There seem to be fundamental differences in how these For more Cengage Learning textbooks, visit www.cengagebrain.co.uk IMPLICIT MEMORY clips. One surprising finding was that, during this part of the experiment, some of the cells continued to fire beyond the clip's ending – just as if they were spending some time memorizing, or at least 'thinking about' what they had just been reacting to. For example, one neuron of one of the patients seemed to be particularly interested in a 5-second clip of The Simpsons; specifically, its firing rate was raised by a factor of 6–7 during that clip compared to any of the other clips, and it continued at that brisk pace for at least 5 seconds following the clip's offset (this particular neuron seemed to enjoy comedy in that it also responded, albeit somewhat less vigorously, to a Seinfeld clip). Other neurons seemed to be specifically interested in particular people, for example one fired particularly rapidly to the actor, Tom Cruise, in two separate clips – one depicting Mr. Cruise in an interview, and the other showing him in a movie. Following a short break, the subjects were then asked to free recall – to recollect as much as they could about the film clips that they had just recently seen. The dramatic finding was that there was a strong correspondence between neurons that fired during the original clip and then again during free-recall or memory only of what was depicted in the beingremembered clip. For example, the neuron that fired selectively to The Simpsons when it was originally shown also responded selectively when the neuron's owner recalled The Simpsons clip when, we emphasize, the clip itself was no longer in view. Indeed, a particular selective neuron would begin to fire about 1.5 second before the patient initiated the recall, suggesting that the neuron's firing was what launched the memory rather than the other way around. It's important to note that this research isn't the first to suggest a correspondence between brain activity during experience and memory. However, the previous research addressed recognition rather than recall, both in humans and in animals, that is, it determined that brain activity was similar when a stimulus was seen originally and then subsequently when the same stimulus was eventually recognized. As is apparent, however, recognition requires that the relevant stimulus be present both originally and during recognition. The exciting and compelling nature of this new research is that it involves recall rather than recognition: The correspondences in brain activity occurs when a particular stimulus is originally experienced and when it is later simply thought about. This suggests a tight activity between experience on the one hand and memory on the other, thereby providing a substantial leap in our basic understanding of how memory works. two kinds of memories are implemented in the brain. The critical evidence comes from brain-scanning experiments (PET). In one experiment (Squire et al., 1992), participants first studied a list of 15 words and then were exposed to three different conditions. The

298 CHAPTER 8 MEMORY implicit-memory condition was the stem-completion task. Half the stems were drawn from the 15 words originally studied and the other half were new; participants were instructed to complete the stems with the first words that came to mind. The second condition of interest involved explicit memory. Again word stems were presented, but now participants were instructed to use them to recall words from the initial list of 15. The third condition was a control. Word stems were presented, and participants were instructed to complete them with the first words that came to mind, but now none of the stems were drawn from the words initially studied. The control condition therefore requires no memory. Participants performed all three of these tasks while their brains were being scanned. Consider first what the brain is doing during the explicit-memory task. From the material presented in the first section of this chapter, we might expect that (1) the hippocampus is involved (remember, this structure is critical in forming long-term memories) and (2) most of the brain activity will be in the right hemisphere (because the task emphasized retrieval, and long-term retrieval involves mainly right-hemisphere processes). This is exactly what was found. More specifically, when brain activity in the explicit-memory condition was compared with that in the control condition, there was increased activation of hippocampal and frontal regions in the right hemisphere. Now consider the implicit-memory condition. Compared with the control condition, it showed decreases in activation rather than increases. That is, priming is reflected in less-than-usual neural activity, as if there has been a 'greasing of the neural wheels'. Implicit memory, then, has the opposite neural consequences of explicit memory, demonstrating a biological difference between the two kinds of memory. This evidence points up once again the interconnections between biological and psychological research. In fact, throughout this chapter we have seen instances of the role of biological evidence in explaining psychological phenomena. In many cases the psychological evidence was obtained first and used to direct subsequent biological research. For example, the cognitive distinction between short-term and long-term memory was made in papers published about a century ago, but only relatively recently have biologically oriented researchers been able to demonstrate some of the neural bases for this key distinction. Biological research is contributing to other areas of the study of memory as well. We now know something about the biological basis of storage in explicit long-term memory and about storage in the visual and verbal buffers of short-term memory. Such knowledge is not only useful in its own right but may also prove helpful in combating the ravages of memory brought about by diseases of aging such as stroke and Alzheimer's. For more Cengage Learning textbooks, visit www.cengagebrain.co.uk

INTERIM SUMMARY | Explicit memory refers to the kind of memory manifested in recall or recognition, when we consciously recollect the past. Implicit memory refers to the kind of memory that manifests itself as an improvement on some perceptual, motor, or cognitive task, with no conscious recollection of the experiences that led to the improvement. | Although explicit memory – particularly recall and recognition of facts – breaks down in amnesia, implicit memory is usually spared. This suggests that there may be separate storage systems for explicit and implicit memory. | Research with normal individuals also indicates that there are separate systems for explicit and implicit memory. Brain-scanning studies with normal individuals show that explicit memory is accompanied by increased neural activity in certain regions, whereas implicit memory is accompanied by a decrease in neural activity in critical regions.

CRITICAL THINKING QUESTIONS 1 On the basis of what you have learned about explicit long-term memory, how would you go about studying for an exam that emphasizes factual recall? 2 We noted that childhood amnesia is related to the development of the hippocampus. What psychological factors might also contribute to childhood amnesia? (Think of things that change dramatically around age 3.)

CONSTRUCTIVE MEMORY Our description of memory processes so far might leave the

impression that a good metaphor for creating, maintaining, and using information in long-term store would be creating, maintaining, and using a video tape. Consider the correspondences:

1. Information is acquired and placed into memory via sensation, perception, and attention in the same way as information is acquired and placed onto a videotape via a video camera.
2. Information is forgotten from long-term store in the same way as videotapes gradually become degraded.
3. Information cannot be retrieved from long-term store in the same way as it is difficult to find a particular

scene on a home video – particularly if there are a lot of scenes on the video and/or it has been a long time since you last retrieved and viewed the scene. Despite these apparent similarities, it would be a grave mistake to use a video recorder as the primary metaphor for understanding memory, because there is a very important and fundamental difference between how memory works and how a video tape works. Unlike a videotape, memory is a constructive and reconstructive process; that is, the memory for an event can and does depart systematically from the objective reality that gave rise to it, both at the time it is formed and then later over time. This crucial difference leads to some of the most interesting and counterintuitive aspects of memory. It almost certainly, for example, underlies Jennifer Thompson's seemingly strange, and certainly catastrophic memory misidentification of the man who raped her. In the subsections that follow, we will first recount a well known personal anecdote that nicely illustrates the reconstructive nature of memory. We will then trace the reconstructive nature of memory from original perception through long-term retrieval. Finally we will briefly discuss the already alluded-to relevance of reconstructive memory to the legal system.

Piaget's childhood memory The renowned Swiss developmental psychologist, Jean Piaget once described a vivid memory from his childhood: one of my first memories would date, if it were true, from my second year. I can still see, most clearly, the following scene, in which I believed until I was about fifteen. I was sitting in my pram, which my nurse was pushing in the Champs Elysees, when a man tried to kidnap me. I was held in by the strap fastened round me while my nurse bravely tried to stand between me and the thief. She received various scratches, and I can still see vaguely those on her face. Then a crowd gathered, a policeman with a short cloak and a white baton came up, and the man took to his heels. I can still see the whole scene, and can even place it near the tube station. A vivid memory indeed! Why then did Piaget believe in it only 'until I was about fifteen'? What happened then? When I was about fifteen, my parents received a letter from my former nurse saying that she had been converted to the Salvation Army. She wanted to confess her past faults, and in particular, to return the watch she had been given as a reward [for saving Baby Jean from the kidnapper]. She had made up the whole story, faking the scratches. I, therefore, must have heard, as a child, the account of this story, which my parents believed, and projected into the past in the form of a visual memory. For more Cengage Learning textbooks, visit www.cengagebrain.co.uk

CONSTRUCTIVE MEMORY So as it happened, Piaget discovered that this memory, vivid though it seemed, was not merely incorrect, but fabricated from whole cloth. When you think about it, the implications of this anecdote are far-reaching: At least some of what we firmly believe to be true is probably fiction. As we will discuss below, this implication is not quite as disturbing as it might seem at first glance, because (1) it takes a special set of circumstances to create a false memory that is this dramatic, and (2) even when such memories are created, they generally do not have any serious real-world

consequences. Be that as it may, however, some false memories, like Jennifer Thompson's, can sometimes have devastating consequences. How do such memories come about? The answer is that they arise from a combination of constructive processes, which can be divided into those occurring at the time of the original encoding of the to-be-remembered event and those occurring after the memory of the remembered event has already been formed. Constructive processes at the time of memory encoding Memory encoding refers to processes that occur at the time that the long-term memory representation of some event is being established. From the perspective of establishing a long-term representation, encoding has two stages: Initial perception (transfer of information into short-term memory) and then whatever processes are entailed in the transfer of information from short-term memory to long-term store. Construction of a false memory can occur at either or both of these stages. Constructive perception In Chapter 5, we discussed the systematic ways in which what is perceived does not necessarily correspond to what is objectively out in the world. In many instances, perception is determined not only by the 'bottom-up' processing of raw, objective, sensory data, but also by the 'topdown' influences of history, knowledge, and expectations. It is important to emphasize here what this means for later memory: What is perceived forms the basis for the initial memory; therefore, if what is originally perceived differs systematically from the objective world, the perceiver's initial memory – and, likely, later memories as well – of what happened will likewise be distorted. To illustrate such constructive perception, we first turn to another personal anecdote, this one from one of the authors of this book (GL). In 1973, GL was visiting a friend who showed him a 'music box', consisting of a cube, approximately six inches on a side, with translucent faces. The box was connected to a stereo system, and as music played, colored lights inside the box lit up in various sequences. With particular light combinations, certain images became clearly visible on the box's translucent

300 CHAPTER 8 MEMORY sides: For instance, there was a Viet Cong soldier on one side, a picture of Bob Dylan on another side, and a picture of the Beatles on yet a third side. Intrigued by this sequence of images, GL and his friend became curious about how they were formed. They supposed that pictures from news magazines had been clipped and affixed to the inside of the box's translucent sides in such a way that they became visible only with certain combinations of colored lights. At length, they took the box apart to investigate. To their amazement, they discovered that there was nothing but random splatters of paint on the translucent sides: The vivid images they had perceived were not there in the world; rather they had been constructed out of randomness. And, even though GL and his friend discovered that their perceptions were illusory, GL maintains to this day a vivid memory of the music-box images that his perceptual system so artfully constructed. A good example of how constructive perception can be demonstrated in the scientific laboratory is found in a phenomenon known as perceptual interference. Perceptual interference was originally described in a 1964 Science article by Jerome Bruner and Mary Potter, who showed observers pictures of common objects (say a rocket) and asked the observers to name the object. The catch was that the objects began by being out-of-focus – sufficiently out-of-focus that they were pretty much unrecognizable – and then were gradually brought into focus. There were two main conditions in the experiment. In the very-out-of-focus (VOF) condition, the objects started out very out of focus, while in the moderately-out-of-focus (MOF) condition, the objects started out only moderately out of focus. The main finding was that the objects had to eventually be more focused in order that the observers were able to recognize them in the VOF condition than in the MOF condition. Why was this? The hypothesis offered by Bruner and Potter was that, upon seeing any out-of-focus object, an observer would generate hypotheses about what the object was

(for instance, an observer might initially hypothesize an out-of-focus rocket to be a pencil). Once a hypothesis was generated, the hypothesis itself largely drove the observer's perception – that is, as the object became more and more focused, the observer would continue to hold the incorrect perception even past the focus level that would allow another observer who hadn't generated any incorrect expectations to perceive the object correctly. Because observers in the VOF condition had more opportunity to form incorrect hypotheses than observers in the MOF condition, it would require a greater degree of focus for eventual correct recognition for the VOF than for the MOF observers.

Generation of inferences As we have pointed out, perception is not sufficient to form a lasting memory of some event. Other processes have to occur that serve to transfer information corresponding to the event from short-term memory to long-term store. For more Cengage Learning textbooks, visit www.cengagebrain.co.uk

Constructive processes can occur here in the form of inferences. Let's illustrate using memory for verbal material. Even when we read something as simple as a sentence we often draw inferences from it and store them along with the sentence in long-term store. This tendency is particularly strong when reading text because inferences are often needed to connect different lines. To illustrate, consider the following story, which was presented to participants in an experiment.

1. Provo is a picturesque kingdom in France.
 2. Corman was heir to the throne of Provo.
 3. He was so tired of waiting.
 4. He thought arsenic would work well.
- When reading this story, participants draw inferences at certain points. At line 3, they infer that Corman wanted to be king, which permits them to connect line 3 to the preceding line. But this is not a necessary inference (Corman could have been waiting for the king to receive him). At line 4, participants infer that Corman had decided to poison the king, so they can connect this line to what preceded it. Again, the inference is not a necessary one (there are people other than the king to poison, and there are other uses of arsenic). When participants' memories were later tested for exactly which lines had been presented, they had trouble distinguishing the story lines from the inferences we just described. It is hard to keep what was actually presented separate from what we added to it (Seifert, Robertson, & Black, 1985).
- Post-event memory reconstruction Earlier we cautioned against thinking of a videotape as an metaphor for memory. A better metaphor would be a file folder (either a physical, cardboard folder or a computer folder) containing the components of some complex enterprise we're working on – say the material for a novel we're writing, which would include our notes, our chapters-in-progress, our photographs, and so on. Every time we open this folder, the contents of it change in some fashion, as our work progresses. And so it is with our memory for some event: Every time we revisit some memory in our minds, the memory changes in some fashion. We may, as we do during memory formation, generate inferences and store these inferences as part of our memory. We may strip away information that doesn't seem to make sense in light of other facts we know or we've learned. We may add new information that is suggested to us by others. All of these kinds of processes fall into the category of post-event memory reconstruction.
- Internally generated inferences There are many ways in which people can make inferences which they then incorporate into their memory. A

recent example reported by Hannigan and Reinitz (2001) described inference in visual memory. In their experiment, observers viewed a slide sequence depicting some common activity, for example shopping in a supermarket. As part of the sequence they saw scenes depicting some relatively unusual situation (e.g., seeing oranges scattered over the supermarket floor). Later, the observers confidently asserted that they had seen a picture that reasonably depicted a possible cause of this situation (e.g., a slide of a woman pulling an orange from the bottom of the pile) when in fact they had never seen the slide. These and related results strongly suggest that, in these situations, viewers make inferences about what must have happened, and incorporate the results of such inferences into their memory of the event. Inferences can also be made based on schemas, a term used to refer to a mental representation of a class of people, objects, events, or situations. Stereotypes, on which we will focus momentarily, are a kind of schema because they represent classes of people (for example, Italians, women, athletes). Schemas can also be used to describe our knowledge about how to act in certain situations. For example, most adults have a schema for how to eat in a restaurant (enter the restaurant, find a table, get a menu from the waiter, order food, and so on). Perceiving and thinking in terms of schemas enables us to process large amounts of information swiftly and economically. Instead of having to perceive and remember all the details of each new person, object, or event we encounter, we can simply note that it is like a schema already in our memory and encode and remember only its most distinctive features. The price we pay for such 'cognitive economy', however, is that an object or event can be distorted if the schema used to encode it does not fit well. Bartlett (1932) was perhaps the first psychologist to systematically study the effects of schemas on memory. He suggested that memory distortions much like those that occur when we fit people into stereotypes can occur when we attempt to fit stories into schemas. Research has confirmed Bartlett's suggestion. For example, after reading a brief story about a character going to a restaurant, people are likely to recall statements about the character eating and paying for a meal even though those actions were never mentioned in the story (Bower, Black, & Turner, 1979). Situations in which memory is driven by schemas seem a far cry from the simpler situations discussed earlier in the chapter. Consider, for example, memory for a list of unrelated words: Here memory processes appear more bottom-up; that is, they function more to preserve the input than to construct something new. However, there is a constructive aspect even to this simple situation, for techniques such as using imagery add meaning to the input. Similarly, when we read a paragraph about a schema-based activity we must still preserve some of its For more Cengage Learning textbooks, visit www.cengagebrain.co.uk

CONSTRUCTIVE MEMORY ^a **IMAGESTATE** / **ALAMY** The stereotype of a 'typical rugby player' may interfere with our encoding of information about these people who could have entirely different characteristics from those included in the stereotype. specifics if we are to recall it correctly. Thus, the two aspects of memory - to preserve and to construct - may always be present, although their relative emphasis may depend on the exact situation. As noted, one important kind of schema is a social stereotype, which concerns personality traits or physical attributes of a whole class of people. We may, for example, have a stereotype of the typical German (intelligent, meticulous, serious) or of the typical Italian (artistic, carefree, fun-loving). These descriptions rarely apply to many people in the class and can often be misleading guides for social interaction. Our concern here, however, is not with the effects of stereotypes on social interaction (see Chapter 18 for a discussion of this) but with their effects on memory. When presented with information about a person, we sometimes stereotype that person (for example, 'He's your typical Italian') and combine the information presented with that in our stereotype. Our memory of the person thus is partly constructed from the stereotype. To the extent that our stereotype does not fit the person, our recall can be

seriously distorted. A British psychologist provides a firsthand account of such a distortion: In the week beginning 23 October, I encountered in the university, a male student of very conspicuously Scandinavian appearance. I recall being very forcibly impressed by the man's Nordic, Viking-like appearance – his fair hair, his blue eyes, and long bones. On several occasions, I recalled his appearance in connection with a Scandinavian correspondence I was then conducting and thought of him as the 'perfect Viking', visualizing him at the helm of a longship crossing the North Sea in quest of adventure. When I again saw the man on 23 November, I did not recognize him, and he had to introduce himself. It was not that I had forgotten what he looked like but that

302 CHAPTER 8 MEMORY his appearance, as I recalled it, had become grossly distorted. He was very different from my recollection of him. His hair was darker, his eyes less blue, his build less muscular, and he was wearing spectacles (as he always does). (Hunter, 1974, pp. 265–66) The psychologist's stereotype of Scandinavians seems to have so overwhelmed any information he actually encoded about the student's appearance that the result was a highly constructed memory. It bore so little resemblance to the student that it could not even serve as a basis for recognition. Externally provided suggestions Post-event reconstruction may also occur as a result of information provided by others. A classic experiment, reported in Elizabeth Loftus and John Palmer (1974) illustrates this process. In the Loftus and Palmer experiment, a group of subjects were shown a film of a car accident (one car running into another). After the film, the subjects were asked a series of questions about the accident that they had just seen. The subjects were divided into two subgroups that were treated identically except for a single word in one of the questions. In particular, the 'hit' group was asked the following question about speed: 'How fast was the car going when it hit the other car?' The corresponding question asked to the 'smashed' group was, 'How fast was the car going when it smashed into the other car?' Other than that, the 'hit' and 'smashed' groups were treated identically. The first finding to emerge from this experiment was that the 'smashed' group provided a higher speed estimate than the 'hit' group (roughly 10.5 mph vs 8 mph). This is interesting, in that it demonstrates the effects of leading questions on the answers that are given. More relevant to EKATERINA PETRYAKOVA j DREAMSTIME.COM In remembering what happened in a traffic accident, we may use general knowledge (such as our knowledge of rules of the road or of the meaning of traffic signals) to construct a more detailed memory. For more Cengage Learning textbooks, visit www.cengagebrain.co.uk the issue of post-event reconstruction, however, was the next part of the procedure: All subjects returned approximately a week later and were asked some additional questions about the accident. One of the questions was 'Did you see any broken glass?' In fact, there had been no broken glass, so the correct answer to the question was 'no'. However, the subjects who had originally been asked about speed using the verb 'smashed' were substantially more likely to incorrectly report the presence of broken glass than were subjects who had originally been asked about speed using the verb 'hit'. The interpretation of this finding is that the verb 'smashed' constituted post-event information. Upon hearing this word, the subjects reconstructed their memory for the accident in such a way as to be consistent with a violent accident in which two cars 'smashed' into one another. Integration into their memory of the broken glass was one consequence of such reconstruction. That is how the non-existent broken glass appeared in those subjects' memories a week later. How powerful is the effect of suggestive information? The Loftus and Palmer study, along with thousands of others that have replicated its basic result over the past three decades, demonstrates the ease of structuring a situation such that a real event is remembered incorrectly with respect to incidental details. Is it possible that, in like fashion, a memory of an entirely fictional event could be created? This seems less likely, based on

intuition and common sense; yet intuition and common sense are incorrect in this regard. To begin with, there are anecdotes of false memories similar to Piaget's described earlier. Even more dramatically, there are occasional reports by people who claim to have experienced events that would be generally considered to be impossible, such as being abducted and experimented on by aliens. Given that these people actually believe that these experiences occurred, they would likely constitute *prima facie* evidence of false memories for complete events. However, interpretation of such anecdotal reports is problematical. First, implausible though such events are, we cannot completely rule out the possibility that they actually occurred. Second, and of somewhat more concern, we do not know that the witnesses are being truthful. One could argue that a few publicity-seeking members of the population carefully make up, and stick to such stories to gain attention. More persuasive scientific evidence comes from recent laboratory studies in which memories of entirely fictional events have been shown to be implantable under controlled conditions. For example, Hyman, Husband, and Billings (1995) reported a study in which college students were asked whether they remembered a relatively unusual, and entirely fictional event (for example, attending a wedding reception and accidentally spilling a punch bowl on the parents of the bride) that subjects were

told occurred when they were relatively young (around 5 years old). Initially, no one remembered these events. However following two interviews about the 'event' a substantial proportion of the students (20 to 25%) reported quite clear 'memories' for parts or all of the events. Indeed, many of the students began 'remembering' details that had never been presented to them (and which, of course, could not have corresponded to objective reality). For example, one subject initially had no recall of the wedding event, but by the second interview, stated, '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'. Other studies (e.g., Loftus & Pickrell, 1995; Loftus, Coan & Pickrell, 1996) have reported similar findings, and another study (Garry, Manning, Loftus, & Sherman, 1996) has reported that it is possible to induce such memories by merely having people imagine fictional renderings of their pasts. It thus appears that in these studies, subjects are using post-event information provided by the experimenters to create memories of entire events that never occurred. In addition, the process of imagining these events spontaneously led to additional, self-generated post-event information, involving additional details, which then also was incorporated. As noted, not all subjects in these experiments actually remembered these false events. In general the percentage of people remembering was approximately 25 percent. The Hyman et al. (1995) study reported some personality correlates of false memory creation. The first was score on the Dissociative Experiences Scale, which measures the extent to which a person has lapses in memory and attention or fails to integrate awareness, thought, and memory. The second correlate was score on the Creative Imagination Scale, which is a measure of hypnotizability and can also be construed as a self-report measure of the vividness of visual imagery.

Constructive memory and the legal system As we have suggested in several of our discussions and examples, constructive memory is particularly important in the legal system where cases are frequently won or lost – and defendants are or are not meted out punishments ranging from prison sentences to death – on the basis of a witness's memory of what did or did not happen. A dramatic example of the consequences of a false memory is the years spent by Ronald Cotton languishing in prison as a result of Jennifer Thompson's false memory of who raped her. This is by no means an isolated incident but, sadly, is one of many known cases and countless unknown cases of miscarriages of justice caused by false memories. In this section, we will spend some time

specifically describing the importance of memory in the legal system. For more Cengage Learning textbooks, visit www.cengagebrain.co.uk

CONSTRUCTIVE MEMORY

Confidence and accuracy

A scientist studying memory in the scientific laboratory has the luxury of knowing whether a participant's memory is correct or incorrect. This is because the scientist, having created the event that the witness is trying to remember, is in a position to compare the participant's response to objective reality. In the real world, however – particularly the real world of a witness whose memory is crucial to the outcome of some legal case – no one has the ability to judge objectively whether the witness is correct or incorrect, because there is no objective record of the original event (with a few minor exceptions, such as the discovery that a crime was captured on video as in the infamous Rodney King case). Therefore the main indication of whether a witness is or is not correct is the witness's confidence that his or her memory is accurate: A witness who says, 'I'm 100% sure that that's the man who raped me', is judged to be more likely correct than a witness who says, 'I'm 75% sure that that's the man who raped me'. This means that a critical question for the legal system is: How good is a witness's confidence as an index of the witness's memory? Common sense says that it's a pretty good indicant. Does scientific evidence back this up? The answer is that although in both the scientific laboratory and in normal everyday life, high confidence is often predictive of high accuracy, psychologists have also delineated the circumstances in which – contrary to common sense – this normal predictive power vanishes. Such circumstances include (1) some original event that causes poor encoding to begin with (e.g., because of short duration, poor lighting, lack of appropriate attention or any of a number of other factors), (2) some form of postevent reconstruction (e.g., inferences or information suggested by others), and (3) the motivation and opportunity to rehearse the reconstructed memory. (For summaries and specific experiments, see Busey, Tunnicliff, Loftus, & Loftus (2000); Deffenbacher (1980); Penrod & Cutler (1995); and Wells, Ferguson, & Lindsay (1981).) For example, Deffenbacher (1980) examined experiments that had measured the relationship between confidence in some memory and the accuracy of that memory. In approximately half of those studies, there was the positive relation between confidence and accuracy that our intuitions would lead us to believe: that is, higher confidence was associated with higher accuracy. In the other half of the experiments, however, there was no relation (or, in some instances, even a negative relation) between confidence and accuracy. Which result was found – that is, whether accuracy was or was not positively related to confidence – depended on the overall circumstances surrounding the formation of the memory. Favorable circumstances (e.g., good lighting, no stress, no post-event information, etc.) lead to the expected positive relation between confidence and accuracy. However, unfavorable circumstances lead

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to no relation, or a negative relation between confidence and accuracy. The reason for this is summarized nicely by Leippe (1980). When encoding circumstances are poor, initial memory is filled with gaps. Suppose, for example, that a person experiences a near-accident in a car (say is almost hit by another car). Because of the brevity and stress of the situation, the person probably would not remember many details – for example, he or she might not remember the make or color of the other car, or whether or not there was a passenger in the car. These would be gaps in the person's memory. But because the event was salient, the person would rehearse the event in his or her mind. In the process of rehearsing, the memory gaps would tend to be filled in. Such filling in could be random, it could be due to expectations, it could be due to post-event information – it could be due to many things, few of them likely to be accurate. The resulting memory would therefore be generally inaccurate. But the rehearsal of this inaccurate memory

would lead to a strong memory, in which the person would have relatively high confidence. An important practical conclusion from these studies: When a witness expresses great confidence in some memory (e.g., in the identification of a defendant as the remembered culprit in some crime) the jury would do well to learn of the events that led up to this confident memory. If the circumstances for forming the original memory were good and there was little cause for postevent memory reconstruction, the jury can reasonably accept the high confidence as evidence of the memory's accuracy. If, on the other hand, the circumstances for forming the original memory were poor, and there was ample reason for post-event memory reconstruction, the jury should discount the witness's high confidence as an index of the memory's accuracy. It is noteworthy that the legal system is finally beginning to take these research findings into account. In April 2001, the state of New Jersey adopted new General Guidelines for identification procedures that were based largely on the kind of research that we have just described. In an accompanying memo, New Jersey Attorney General James Farmer noted that it is important to guard against identification procedures which may invest a witness with a false sense of confidence, and goes on to say, 'Studies have established that the confidence level that witnesses demonstrate regarding their identifications is the primary determinant of whether jurors accept identifications as accurate and reliable'. Suggestive information and children's memories Young children appear to be particularly susceptible to suggestive information, particularly while they are being interviewed. Ceci and Bruck (1993) describe a variety of studies demonstrating this kind of suggestibility. The problem is particularly acute because children are often interviewed about crimes by interviewers who, wittingly or unwittingly, provide a great deal of suggestive information in the course of the interview. An example of a recently reported experiment demonstrating the consequences of this sort of confirmatory interview technique worked as follows. First, a trained social worker was given a fact sheet about a particular event in which a child had participated. This fact sheet contained both actual actions that had happened during the event, and false actions – actions that had not actually occurred. The social worker was then asked to interview the child about the event. She was asked specifically not to ask leading questions. Several results emerged from this procedure. First, the child being interviewed eventually recalled the false actions with a good deal of confidence, thereby indicating that the interviewer had 'infected' the child with her preconceptions about what had happened. Second, other professionals couldn't tell which of the things the child recalled were the real actions, and which were the falsely implanted actions. So this is a noteworthy example of an instance in which the interview itself – unbiased though the professional interviewer tried to make it – was obviously effective in conveying the interviewer's pre-existing biases to the child and actually altering the child's memory about what happened – indeed, altering it in such a fashion that other professionals couldn't tell what in the

³ GAITANO/CORBIS A very confident eyewitness, while persuasive to a jury, may nevertheless be completely incorrect.

child's memory was based on actual experience and what was based on after-the-fact suggested information. Forced confessions A growing body of work has demonstrated that interrogation techniques carried out by police and other investigators have been able to produce genuinely false memories (and confessions) of crimes that the suspects can be objectively shown not to have committed. Detailed reports and summaries of these general issues are provided by Kassin (1997), Leo (1996) and Ofshe (1992). These writers have demonstrated that false memories can be created in the minds of innocent people by techniques that include, but are not limited to, (a) being told that there is unambiguous evidence (such as fingerprints) proving their culpability, (b) being

told that they were drunk or were otherwise impaired so that they wouldn't have remembered the crime, (c) being told that awful crimes are repressed and if they try hard they will be able to 'recover' these repressed memories, and (d) being told that they are suffering from multiple personality disorder and that the crime was committed by another of their personalities. Richard Ofshe (1992) provides a dramatic, indisputable example of such a sequence of false memories. In a well-known case (described in a series of New Yorker articles) Paul Ingram, a high-ranking employee of the Thurston County (WA) Sheriff's Department, was accused by his two daughters of having raped and abused them over many years as part of a series of satanic cult rituals. Ingram initially claimed innocence, but following a lengthy series of police interrogations began to admit to the crimes and also began to have increasingly vivid 'memories' of the details. Ofshe, a sociologist at the University of California, Berkeley with expertise in cult-related matters was retained by the prosecution to advise them in the Ingram case. In the course of his investigation, Ofshe concluded that (a) there was zero evidence of the presumed cult activity that constituted the foundation of the accusations against Ingram and (b) that many of Ingram's 'memories' – detailed though they were, and confident of their validity as Ingram was – could not logically be true, but rather were almost certainly created as a result of the intense suggestion provided during interrogations by police officers and other authority figures. To confirm his false-memory hypothesis, Ofshe carried out an experiment wherein he accused Ingram of a specific event that all other participants agreed did not happen (this fictional event consisted of Ingram's successfully demanding that his son and daughter have sex with one another and observing them do so). Ingram initially reported not remembering this event. However, upon intensely thinking about the possibility of it having happened, in conjunction with the accusation by a trusted authority figure (Ofshe), Ingram began to not only 'remember' the fabricated event itself, but also to generate For more Cengage Learning textbooks, visit www.cengagebrain.co.uk CONSTRUCTIVE MEMORY minute details about how the event unfolded. Ingram eventually claimed this memory to be very real to him. Even when stupendous efforts by all parties (Ofshe, the police, and all other interrogators) were eventually made to convince Ingram that the event was not real, but was part of an experiment, Ingram still steadfastly and sincerely refused to cease believing that the incident had actually occurred. Eventually, however, following the cessation of the intense interrogation, Mr. Ingram began to question and recant the memories that he had originally formed. The Ingram case, while probably the most public and dramatic of false memories created by interrogation, is not an isolated anomaly. Kassin (1997) follows a description of this same case by remarking that, There are other remarkable cases as well that involve coerced-internalized confessions [by which Kassin means confessions based on false memories that are actually believed by the defendant to be true]. The names, places, and dates may change, but they all have two factors in common: (a) a suspect who is 'vulnerable' – that is, one whose memory is vulnerable by virtue of his or her youth, interpersonal trust, naiveté, suggestibility, lack of intelligence, stress, fatigue, alcohol or drug abuse and (b) the presentation of false evidence such as a rigged polygraph or forensic tests (e.g., bloodstains, semen, hair, fingerprints), statements supposedly made by an accomplice, or a staged eyewitness identification as a way to convince the beleaguered suspect that he or she is guilty. (p. 227)

Jennifer Thompson's memory We conclude this section by returning to the case of Jennifer Thompson. Why was it that Ms. Thompson both misidentified Ronald Cotton and failed to identify the actual rapist? Although we don't know the answers to these questions with absolute certainty, we can, on the basis of what is known about reconstructive memory, certainly offer some reasonable hypotheses. To begin with, the circumstances surrounding the original event – the rape – were far from optimal from the perspective of Ms. Thompson's being able to memorize the

rapist's appearance. It was dark, Ms. Thompson was terrified, and her attention was likely on what was most important at the moment – trying to avoid being raped and/or to escape – than with what her attacker looked like. Therefore it is likely that her original memory was poor. Why then did Ms. Thompson identify Mr. Cotton to begin with? This is unclear; however, based on other evidence the police believed that he was the culprit and may well have suggested this to her during her original identification of him from mug shots. Once she had identified him in this fashion, however, she re-identified

306 CHAPTER 8 MEMORY him in a live lineup – but one containing Cotton, whose picture she had already seen, along with five other individuals who were completely unfamiliar to her; it is therefore no surprise that she picked out Mr. Cotton from the lineup. The important thing, however, is that Mr. Cotton's picture that she selected during the original identification, along with Mr. Cotton himself whom she selected from the lineup, provided a fertile source of post-event information – information that allowed Ms. Thompson to reconstruct her memory for the original event such that her originally hazy memory of the original rapist was transformed into a very vivid memory of Mr. Cotton. This reconstruction had three important consequences. First, it formed the basis for Ms. Thompson's very confident in-court identification that proved to be the basis for Mr. Cotton's conviction. Second, it prevented her from correctly recognizing Bobby Poole as the man who had actually been there. Finally, it evidently formed the basis for Ms. Thompson's recollection of how well she had studied him. Notice how she described this process: 'I looked at his hairline; I looked for scars, for tattoos, for anything that would help me identify him'. But did she? If so, why did she recognize the wrong man? The answer is probably that after having constructed an excellent memory of Ronald Cotton as a result of seeing him during the identification procedures, she constructed an accompanying memory of the process by which her image of him got formed.

Memory errors and normal memory As the previous sections illustrate, memory is often far from accurate. Recently psychologists and neuroscientists have begun an attempt to delineate the various mechanisms that produce memory illusions, which occur when people confidently 'remember' events that did not occur at all. The study of memory illusions is rapidly gaining in popularity because it has obvious real-world applications (for instance, to legal issues involving eyewitness testimony) while at the same time contributing to our understanding of normal memory processes. Many specific memory illusions have been identified. Some have already been described in this text, including the integration of post-event information into memories and misremembering inferred information as events that were experienced. One especially heavily studied memory illusion is the DRM effect (the letters refer to James Deese, Henry Roediger, and Kathleen McDermott, who have extensively studied the illusion). Here participants are read lists of words and then immediately asked to recall them. The trick is that the words on each list are all close associates (e.g., sit, table, seat, etc.) of a central 'theme' word (e.g., chair) which is not included on the list. The startling finding is that participants are more likely to 'remember' the never-presented theme word than to remember words that had actually been presented on the list. For more Cengage Learning textbooks, visit www.cengagebrain.co.uk list (Roediger & McDermott, 1995). Memory conjunction errors are another popular illusion to study. Here participants are presented with to-be-remembered items (e.g., words, such as SOMEPLACE and ANYWHERE), and then receive a recognition test including new items constructed from parts of previously studied items (e.g., SOMEWHERE). Participants have a very strong tendency to claim that these new items had been presented previously (e.g., Reinitz & Hannigan, 2004). Although each of these illusions is distinct, they may each be described as a failure to accurately remember the source of information

in memory. Marcia Johnson and her colleagues (Mitchell & Johnson, 2000; Johnson, Hashtroudi, & Lindsay, 1993) have proposed that an important memory process, called source monitoring, involves attributing information in memory to its source. For instance, if you remember having heard that a new film is worth seeing it is helpful to be able to remember who told you this so that you can decide whether you share a taste in films. Source monitoring processes identify the most likely source in an inferential manner – for instance, if you know that you heard about the film very recently then you will consider only sources that you have recently encountered. Because source monitoring is based in inference it sometimes fails, leading to inaccurate memories for the source of information. This may help explain a number of memory illusions. For example, people may misattribute the source of post-event information to the event itself, leading to confident but erroneous memories. Similarly, the presentation of multiple associated words in a DRM experiment may cause the theme word to come to mind; participants may then misattribute the source of their recent memory for the theme word to the lists they had heard. In the case of memory conjunction errors, participants may misremember the word parts as arising from the same source word. Thus memory illusions illustrate that memory for information is separate from memory for its source, and show the importance of source monitoring for memory accuracy. Source memory has been shown to decline as a part of normal cognitive aging. For instance, in an experiment by Schacter et al. (1991) two different individuals read words out loud to younger and older adult participants. Participants in the two age groups were about the same at distinguishing old from new words on a recognition test; however, the younger group was much more accurate at remembering the source of the words (which of the individuals had originally read each word). Thus older adults are likely to be more susceptible to many memory illusions. This in turn may lead to difficulties for older adults – for instance, some older adults complain that they sometimes have trouble remembering whether they recently took their medicine, or whether they instead recently thought about taking their medicine. In this case they have a recent memory about taking medicine, but have difficulty remembering whether the source was an internal thought or an actual behavior.

INTERIM SUMMARY | Both experimental and anecdotal evidence indicate that, unlike a videotape, a memory is constructed and reconstructed on the basis of expectations and knowledge. In this sense, memory for some event often shows systematic departures from the event's objective reality. | Memory reconstruction can occur at the time the memory is originally formed via perceptual errors of various sorts. | More often, memory reconstruction occurs at varying times after its formation on the basis of various kinds of post-event information. | Memory reconstruction forms the basis for memories that, although systematically incorrect, seem very real and are recounted with a great deal of confidence. This is critical in various practical settings, notably the legal system, which often relies heavily on eyewitness memory. | Like perceptual errors such as those entailed in illusions (see Chapter 5) errors are a normal, and probably a useful characteristic of normal memory. If memories were complete and accurate, they would overwhelm our information-processing systems!

CRITICAL THINKING QUESTIONS

- 1 Suppose that on their tenth anniversary, Jason and his wife Kate are discussing their wedding. Jason laughingly recounts the story of how Kate's mother accidentally stumbled over the food table and spilled a bottle of champagne. Kate, not so laughingly, claims that it was Jason's mother who had had the embarrassing accident. Use what is known about constructive and reconstructive memories to construct a sequence of events that might have led to this disagreement.
- 2 It is generally agreed that the accuracy of memory declines over time. Describe two separate reasons for why this occurs. (Hint: You learned about one in the previous section and about the other in this section).

IMPROVING MEMORY Having considered the basics of working memory and long-term memory, we are ready to tackle the question of how memory can be improved, focusing primarily on explicit memory. First we will consider how to increase For more Cengage Learning textbooks, visit www.cengagebrain.co.uk IMPROVING MEMORY the working memory span. Then we will turn to a variety of methods for improving long-term memory; these methods work by increasing the efficiency of encoding and retrieval. Chunking and memory span For most of us, the capacity of working memory cannot be increased beyond 7 2 chunks. However, we can enlarge the size of a chunk and thereby increase the number of items in our memory span. We demonstrated this point earlier: Given the string 149-2177-619-96, we can recall all 12 digits if we recode the string into three chunks – 1492-1776-1996 – and store them in working memory. Although recoding digits into familiar dates works nicely in this example, it will not work with most digit strings because we have not memorized enough significant dates. But if a recoding system could be developed that worked with virtually any string, working memory span for numbers could be dramatically improved. Psychologists have studied an individual who discovered such a general-purpose recoding system and used it to increase his memory span from 7 to almost 80 random digits (see Figure 8.14). This person, referred to as S.F., had average memory abilities and average intelligence for a college student. For a year and a half he engaged in a memory-span task for about three to five hours per week. During this extensive practice S.F., a good long-distance runner, devised the strategy of recoding sets of four digits into running times. For example, S.F. would 60 Digit span 20 0 20 40 Practice days Figure 8.14 Number of Digits Recalled by S.F. S.F. greatly increased his memory span for digits by devising a recoding system that used chunking and hierarchical organization. Total practice time was about 215 hours. (Adapted from ‘Acquisition of a Memory Skill’, reprinted by permission from Science, Vol. 208, 1980, pp. 1181–1182 by I. A. Ericsson, et al. Copyright © 1980 by American Association for the Advancement of Science.)

308 CHAPTER 8 MEMORY recode 3492 as ‘3:49.2 – world class time for the mile’, which for him was a single chunk. Since S.F. was familiar with many running times (that is, he had them stored in long-term memory), he could readily chunk most sets of four digits. In cases in which he could not (for example, 1771 cannot be a running time because the third digit is too large), he tried to recode the four digits into either a familiar date or the age of some person or object known to him. Use of these recoding systems enabled S.F. to increase his memory span from 7 to 28 digits (because each of S.F.’s 7 chunks contains 4 digits). He then built up his memory span to nearly 80 digits by organizing the running times in a hierarchy. Thus, one chunk in S.F.’s working memory might have pointed to three running times; at the time of recall, S.F. would go from this chunk to the first running time and produce its 4 digits, then move to the second running time in the chunk and produce its digits, and so on. One chunk was therefore worth 12 digits. In this way S.F. achieved his remarkable memory span. The expansion of his memory capacity was due to increasing the size of a chunk (by relating the items to information in long-term memory), not to increasing the number of chunks that working memory can hold. When he switched from digits to letters, his memory span went back to 7 – that is, 7 letters (Ericsson, Chase, & Faloan, 1980). This research on working memory is fairly recent. Interest in expanding long-term memory has a longer history and is the focus of the rest of this section. We will look first at how material can be encoded to make it easier to retrieve and then consider how the act of retrieval itself can be improved. Imagery and encoding We mentioned earlier that we can improve the recall of unrelated items by adding meaningful connections between them at the time of encoding, for these connections will facilitate later retrieval. Mental images have been found to be particularly useful for connecting pairs of unrelated

items, and for this reason imagery is the major ingredient in many mnemonic systems, or systems for aiding memory. A well-known mnemonic system is the method of loci (loci is the Latin word for 'places'). This method works especially well with an ordered sequence of arbitrary items such as unrelated words. The first step is to commit to memory an ordered sequence of places – such as the locations you would come upon during a slow walk through your house. You enter through the front door into a hallway, move next to the bookcase in the living room, then to the television in the living room, then to the curtains at the window, and so on. Once you can easily take this mental walk, you are ready to memorize as many unrelated words as there are locations on your walk. You form an image that relates the first word to the first location, another For more Cengage Learning textbooks, visit www.cengagebrain.co.uk Figure 8.15 A Mnemonic System. The method of loci aids memory by associating items (here, entries on a shopping list) with an ordered sequence of places. image that relates the second word to the second location, and so on. If the words are items on a shopping list – for example, 'bread', 'eggs', 'beer', 'milk', and 'bacon' – you might imagine a slice of bread nailed to your front door, an egg hanging from the light cord in the hallway, a can of beer in the bookcase, a milk commercial playing on your television, and curtains made from giant strips of bacon (see Figure 8.15). Once you have memorized the items in this way, you can easily recall them in order by simply taking your mentalwalk again. Eachlocation will retrievean image, and each image will retrieve a word. The method clearly works and is a favorite among people who perform memory feats professionally. Imagery is also used in the key-word method for learning words in a foreign language. (See Table 8.3). Suppose that you had to learn that the Spanish word caballo means 'horse'. The key-word method has two steps. The first is to find a part of the foreign word that sounds like an English word. Since caballo is pronounced, roughly, 'cob-eye-yo', 'eye' could serve as the key word. The next step is to form an image that connects the key word and the English equivalent – for example, a giant eye being kicked by a horse (see Figure 8.16). This should establish a meaningful connection between the Spanish and English words. To recall the meaning of caballo, you would first retrieve the key word 'eye' and then the stored image that links it to 'horse'. The key-word method may sound complicated, but studies have shown that it is very helpful in learning the vocabulary of a foreign language (Atkinson, 1975; Pressley, Levin, & Delaney, 1982).

Table 8.3 The Key-Word Method Examples of key words used to link Spanish words to their English translations. For example, when the Spanish word muleta is pronounced, part of it sounds like the English word 'mule'. Thus, 'mule' could be used as the key word and linked to the English translation by forming an image of a mule standing erect on a crutch. Spanish Key word English caballo (eye) horse charco (charcoal) puddle muleta (mule) crutch clavo (claw) nail lagartija (log) lizard payaso (pie) clown hiio (eel) thread tenaza (tennis) pliers jabon (bone) soap carpa (carp) tent pato (pot) duck Elaboration and encoding We have seen that the more we elaborate items, the more we can subsequently recall or recognize them. This phenomenon arises because the more connections we establish between items, the larger the number of retrieval possibilities. The practical implications of these findings are straightforward: If you want to remember a particular fact, expand on its meaning. To illustrate, suppose you read a newspaper article about an epidemic in Brooklyn that health officials are trying to contain. To expand on this, you could ask yourself questions about the causes and consequences of the epidemic: Was the disease carried by a person or by an animal? Was it transmitted through the water supply? To contain the epidemic, will officials go so far as to stop outsiders from visiting Brooklyn? How long is the epidemic likely to last? Questions about the causes and consequences of an event are especially effective because

each question sets up a meaningful connection, or retrieval path, to the event. Context and retrieval Since context is a powerful retrieval cue, we can improve our memory by restoring the context in which the learning took place. If your psychology class always meets in a particular room, your recall of the lecture material may be better when you are in that room than when you are in a different building because the context of the room serves For more Cengage Learning textbooks, visit www.cengagebrain.co.uk IMPROVING MEMORY Caballo eye Horse Pato pot Duck Figure 8.16 Foreign Language Learning. Mental images can be used to associate spoken Spanish words with corresponding English words. Here, possible images for learning the Spanish words for 'horse' and 'duck' are illustrated. as a cue for retrieving the lecture material. Most often, though, when we have to remember something we cannot physically return to the context in which we learned it. If you are having difficulty remembering the name of a school classmate, you are not about to go back to your school just to recall it. However, you can try to re-create the context mentally. To retrieve the long-forgotten name, you might think of different classes, clubs, and other activities that you participated in during school to see whether any of these bring to mind the name you are seeking. When participants used these techniques in an actual experiment, they were often able to recall the names of school classmates that they were sure they had forgotten (Williams & Hollan, 1981). Organization We know that organization during encoding improves subsequent retrieval. This principle can be put to great practical use: We are capable of storing and retrieving a massive amount of information if we organize it appropriately. Some experiments have investigated organizational devices that can be used to learn many unrelated items. In one study, participants memorized lists of unrelated words by organizing the words in each list into a story, as illustrated in Figure 8.17. When tested for 12 such lists (a

total of 120 words), participants recalled more than 90 percent of the words. Control participants, who did not use an organizational strategy, recalled only about 10 percent of the words! The performance of the experimental participants appears to be a remarkable memory feat, but anyone armed with an organizational strategy can do it. At this point you might concede that psychologists have devised some ingenious techniques for organizing lists of unrelated items. But, you argue, what you have to remember are not lists of unrelated items but stories you were told, lectures you have heard, and readings like the text of this chapter. Isn't this kind of material already organized, and doesn't this mean that the previously mentioned techniques are of limited value? Yes and no. Yes, this chapter is more than a list of unrelated sentences, but – and this is the essential point – there is always a problem of organization with any lengthy material. Later you may be able to recall that elaborating meaning aids learning, but this may not bring to mind anything about, for example, acoustic coding in shortterm memory. The two topics do not seem to be intimately related, but there is a relationship between them: Both deal with encoding phenomena. The best way to see that relationship is to note the headings and subheadings in the chapter, because these show how the material in the chapter is organized. An effective way to study is to keep this organization in mind. You might, for example, try to capture part of the chapter's organization by sketching a hierarchical tree like the one shown in Figure 8.18. You can use this hierarchy to guide your memory search whenever you have to retrieve information about this chapter. It may be even more helpful, though, to make your own hierarchical outline of the chapter. Memory seems to benefit most when the organization is done by the person who needs to remember the material. A LUMBERJACK DARTed out of a forest, SKATED around a HEDGE past a COLONY of DUCKs. He tripped on some FURNITURE, tearing his STOCKING while hastening toward the PILLOW where his MISTRESS lay. A VEGETABLE can be a useful INSTRUMENT for a COLLEGE

student. A carrot can be a NAIL for your FENCE or BASIN. But a MERCHANT of the QUEEN would SCALE that fence and feed the carrot to a GOAT. One night at DINNER I had the NERVE to bring my TEACHER. There had been a FLOOD that day, and the rain BARREL was sure to RATTLE. There was, however, a VESSEL in the HARBOR carrying this ARTIST to my CASTLE. Figure 8.17 Organizing Words Into a Story. Three examples in which a list of 10 unrelated words is turned into a story. The capitalized items are the words on the list. (After Bower & Clark, 1969) Consolidation Storage Retrieval Acoustic code Visual code Encoding Retrieval Encoding Errors in the recall of consonants Fades quickly Limited capacity (7 ± 2) displacement and decay Search and activation models Adding meaningful connections; elaboration of meaning Retrieval failures; interference; search and activation models Storage Role of hippocampus LONG-TERM (explicit) MEMORY WORKING Figure 8.18 A Hierarchical Tree. Creating hierarchical trees of chapters in textbooks can help students retrieve information about those chapters. This tree represents the organization of part of this chapter. CHAPTER 8 MEMORY For more Cengage Learning textbooks, visit www.cengagebrain.co.uk

80 Immediate recall Percentage of recall 40 20 Recall after 4 hours 0 20 60 Percentage of study time spent in self-recitation Figure 8.19 Practicing Retrieval. Recall can be improved by spending a large proportion of study time attempting retrieval rather than silently studying. Results are shown for tests given immediately and 4 hours after completing study. (After Gates, 1917) Practicing retrieval Another way to improve retrieval is to practice it – that is, to ask yourself questions about what you are trying to learn. Suppose that you have two hours in which to study an assignment that can be read in approximately 30 minutes. Reading and rereading the assignment four times is generally less effective than reading it once and asking yourself questions about it. You can then reread selected parts to clear up points that were difficult to retrieve the first time around, perhaps elaborating these points so that they become well connected to one another and to the rest of the assignment. Attempting retrieval is an efficient use of study time. This was demonstrated long ago by experiments using material similar to that actually learned in courses (see Figure 8.19). For more Cengage Learning textbooks, visit www.cengagebrain.co.uk IMPROVING MEMORY A procedure akin to practicing retrieval may be useful in implicit memory situations. The procedure, referred to as mental practice, consists of imagining the rehearsal of a perceptual motor skill without actually moving any part of the body. For example, you might imagine yourself swinging at a tennis ball, making mental corrections when the imagined swing seems faulty, without moving your arm. Such mental practice can improve performance of the skill, particularly if the mental practice is interspersed with actual physical practice (Swets & Bjork, 1990). INTERIM SUMMARY I Although we cannot increase the capacity of working memory, we can use recoding schemes to enlarge the size of a chunk and thereby increase the memory span. I One way to improve encoding and retrieval is to use imagery, which is the basic principle underlying mnemonic systems such as the method of loci and the key word method. I Other ways to improve encoding (and subsequent retrieval) are to elaborate the meaning of the items and to organize the material during encoding (hierarchical organization seems preferable). CRITICAL THINKING QUESTIONS 1 Suppose that an actor has a very long speech to memorize. How might she best go about such memorization? 2 Given what we know about context and retrieval, what would be the most efficient way to study for a statistics exam?

SEEING BOTH SIDES ARE REPRESSED MEMORIES VALID? Recovered memories or false memories? Kathy Pezdek, Clairmont College In recent years, a number of critical questions have been raised regarding the credibility of adults' memory for their childhood experiences. At the heart of these

claims is the view that it is relatively easy to plant memories for events that did not occur. Let me say up front that surely there have been some false memories for incest, and surely some therapeutic techniques are more likely to foster false memories than others. Further, it is surely possible to find some individuals who are so highly suggestible that one could readily get them to believe anything. However, the claim by those who promote the suggestibility explanation for long forgotten memories of childhood sexual abuse assumes an extremely strong construct of memory suggestibility. The truth is that the cognitive research on the suggestibility of memory simply does not support the existence of a suggestibility construct that is sufficiently robust to explain this phenomenon. How do cognitive psychologists study the suggestibility of memory? This text refers to an experiment by Loftus, Schooler, and Wagenaar (1985) in which participants were more likely to think that they saw broken glass in the film of a traffic accident (broken glass was not present in the film) if they had been asked a previous question that included the word 'smashed' rather than 'hit'. This finding is real, but it involves an insignificant detail of an insignificant event, and even so, across a number of studies using this paradigm, the difference in the rate of responding positively to the question about the broken glass, for example, in the control ('hit') versus the misled ('smashed') condition is typically only 20%–30%. Thus, although this suggestibility effect is a real one, it is neither large nor robust. What evidence supports the conclusion that a memory can be planted for an event that never occurred? The most frequently cited study in this regard is the 'lost in the mall' study by Loftus and Pickrell (1995). These researchers had 24 volunteers suggest to offspring or younger siblings that they had been lost in a shopping mall as a child. Six of the 24 participants reported full or partial memory of the false event. However, these results would not be expected to generalize to the situation of having a therapist plant a false memory for incest. Being lost while shopping is not such a remarkable memory implant. Children are often warned about the dangers of getting lost, have fears about getting lost, are commonly read classic tales about children who get lost (e.g., Hansel and Gretel, Pinocchio, Goldilocks and the Three Bears), and, in fact, often do get lost, if only for a few frightening minutes. Therefore, it would be expected that most children would have a pre-existing script for getting lost that would be accessed by the suggestion of a particular instance of getting lost in the Loftus study. In sharp contrast, it is hardly likely that most children would have a pre-existing script for incestuous sexual contact. My graduate students and I have conducted a number of studies to test whether Loftus's findings regarding planting a false memory generalize to less plausible events. In one of these studies (Pezdek, Finger, & Hodge, 1997), 20 volunteers read descriptions of one true event and two false events to a younger sibling or close relative. The plausible false event described the relative being lost in a mall while shopping; the implausible false event described the relative receiving a rectal enema. After being read each event, participants were asked what they remembered about the event. Only three of the false events were 'remembered' by any of the participants, and all were the plausible event regarding being lost in the mall. No one believed the implausible false event. Implausible events such as parent-child intercourse or receiving an enema are simply unlikely to be suggestively planted in memory because most children do not have preexisting scripts for these events. At a broader level, it is also important to consider that although the 'false memory debate' most often concerns reported memories for childhood sexual abuse, this is only one of the many sources of psychogenic amnesia for which memory recovery has been reported. It is well documented that combat exposure and other violent events can produce psychogenic amnesia (for a review, see Arrigo & Pezdek, 1997). Those who doubt the reality of repressed memory for sexual abuse need to explain psychogenic amnesia for these other types of trauma as well. In conclusion, cognitive research offers no support for the claim that implausible false events such as childhood

sexual abuse are easily planted in memory. Although there are some techniques that can be used to suggestively plant bizarre false memories in some highly suggestive individuals, there is no evidence that this is a widespread phenomenon, and promoting this view is not only misleading, it is not good science. Kathy Pezdek CHAPTER 8 MEMORY For more Cengage Learning textbooks, visit www.cengagebrain.co.uk

SEEING BOTH SIDES ARE REPRESSED MEMORIES VALID? Repressed Memories: A Dangerous Belief? Elizabeth F. Loftus, University of California, Irvine In a land transformed by science, pseudoscientific beliefs live on. It was a set of wild, wacky, and dangerous beliefs that led to serious problems for Nadean Cool, a 44-year-old nurse's aide in Appleton, Wisconsin. Nadean had sought therapy in late 1986 to help her cope with her reaction to a traumatic event that her daughter had experienced. During therapy, her psychiatrist used hypnosis and other methods to dig out allegedly buried memories of abuse. In the process his patient became convinced that she had repressed memories of being in a satanic cult, of eating babies, of being raped, of having sex with animals, of being forced to watch the murder of her 8-year-old friend. She came to believe that she had over 120 separate personalities – children, adults, angels, and even a duck – all because, she was told, she had experienced such severe childhood sexual and physical abuse. In addition to hypnosis and other suggestive techniques, the psychiatrist also performed exorcisms on Nadean, one of which lasted five hours, replete with the sprinkling of holy water and screams for Satan to leave Nadean's body. When Nadean came to realize that false memories had been planted, she sued for malpractice; her case settled, mid-trial, in early 1997, for \$2.4 million dollars (see McHugh et al., 2004 for more cases like Nadean's, and an analysis of what happens to these individuals and their families after this kind of experience). Hundreds of people, mostly women, have developed memories in therapy of extensive brutalization that they claimed they repressed, and they later retracted these. How do we know that the abuse memories aren't real and the retractions false? One clue is that the women would sometimes develop memories that were psychologically or biologically impossible, such as detailed memories of abuse occurring at the age of 3 months or memories of being forced to abort a baby by coat hanger when physical evidence confirmed virginity. How is it possible for people to develop such elaborate and confident false memories? I began studying how false memories take root back in the early 1970s, with a series of experiments on the 'misinformation effect'. When people witness an event and are later exposed to new and misleading information about that event, their recollections often become distorted. The misinformation invades us, like a Trojan horse, precisely because we do not detect its influence. We showed it was relatively easy, with a little bit of suggestion to, for example, make witnesses to an accident believe they saw a car go through a stop sign, when it was actually a yield sign. For a review of 30 years of research on the misinformation effect, see Loftus (2005). Later studies showed that suggestive information not only can alter the details of a recent experience, but also can plant entirely false beliefs and memories in the minds of people. People have been convinced that, as children, they were lost in a shopping mall for an extended time and rescued by an elderly person, that they had an accident at a family wedding, that they nearly drowned and were rescued by a lifeguard, and that they were victims of a vicious animal attack. In some studies as many as half the individuals who underwent suggestive interviewing came to develop either full or partial false childhood memories. (For a review of many of these studies and a comprehensive review of the science of false memory see Brainerd & Reyna, 2005). Hypnosis, suggestive dream interpretation, and guided imagination – techniques used by some psychotherapists – have all been shown to be successful ways of feeding people erroneous material and getting them to accept it,

and develop 'rich false memories'. By this I mean false memories that contain lots of sensory detail, are held with confidence, and expressed with emotion. Of course, simply because we can plant false childhood memories in subjects in no way implies that memories that arise after suggestion, or imagination, or dream interpretation are all necessarily false. In no way does this invalidate the experiences of the many thousands of individuals who have truly been abused and are later in life reminded of the experience. This happens. But we need to keep in mind the words of Richard McNally from Harvard University who had this to say in his book *Remembering Trauma*: 'The notion that the mind protects itself by repressing or dissociating memories of trauma, rendering them inaccessible to awareness, is a piece of psychiatric folklore devoid of convincing empirical support' (McNally, 2003, pp. 111–12). Sadly, the mental health professionals who contributed to the problems experienced by patients like Nadean Cool almost never admit that they were wrong (Tavris & Aronson, 2007). They should realize, and we too need to keep in mind, that without corroboration, there is little that even the most experienced evaluator can use to differentiate the true memories from those suggestively planted. Apart from bearing on the controversy about repressed memories that plagued our society for more than a decade, the modern research does reveal important ways in which our memories are malleable, and it reveals much about the rather flimsy curtain that sometimes separates memory and imagination. Elizabeth F. Loftus

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314 CHAPTER 8 MEMORY CHAPTER SUMMARY There are three stages of memory: encoding, storage, and retrieval. Encoding refers to the transformation of information into the kind of code or representation that memory can accept; storage refers to retention of the encoded information; and retrieval refers to the process by which information is recovered from memory. The three stages may operate differently in situations that require us to store material for a matter of seconds (working memory) and in situations that require us to store material for longer intervals (long-term memory). Moreover, different long-term memory systems seem to be involved in storing facts, which are part of explicit memory, and skills, which are part of implicit memory. There is increasing biological evidence for these distinctions. Recent brain-scanning studies of long-term memory indicate that most of the brain regions activated during encoding are in the left hemisphere and that most of the regions activated during retrieval are in the right hemisphere. Evidence from both animal studies and studies of humans with brain damage indicates that different brain regions may mediate working memory and long-term memory. In particular, in both humans and other mammals, damage to the hippocampal system impairs performance on long-term memory tasks but not on working memory tasks. There are three kinds of memory that differ in terms of their temporal characteristics: Sensory memory lasts over a few hundreds of milliseconds; short-term memory (now called working memory) operates over seconds; long-term store operates over times ranging from minutes to years. Sensory memory has a very large capacity but decays in a very short time. Information within sensory memory that is attended to is transferred to the next memory, working memory. Information in working memory may be encoded acoustically or visually depending on the nature of the task at hand. The most striking fact about working memory is that its storage capacity is limited to 7 ± 2 items, or chunks. While we are limited in the number of chunks we can remember, we can increase the size of a chunk by using

For more Cengage Learning textbooks, visit www.cengagebrain.co.uk information in long-term memory to recode incoming material into larger meaningful units. Information can be lost or forgotten from working memory. One cause of forgetting is that information decays with time; another is that new

items displace old ones. Retrieval slows down as the number of items in working memory increases. Some have taken this result to indicate that retrieval involves a search process, whereas others have interpreted the result in terms of an activation process. Working memory is used in solving various kinds of problems, such as mental arithmetic, geometric analogies, and answering questions about text. However, working memory does not seem to be involved in the understanding of relatively simple sentences. Working memory may also serve as a way station to permanent memory, in that information may reside in working memory while it is being encoded into long-term memory. Information in long-term memory is usually encoded according to its meaning. If the items to be remembered are meaningful but the connections between them are not, memory can be improved by adding meaningful connections that provide retrieval paths. The more one elaborates the meaning of material, the better memory of that material will be. Many cases of forgetting in long-term memory are due to retrieval failures (the information is there but cannot be found). Retrieval failures are more likely to occur when there is interference from items associated with the same retrieval cue. Such interference effects suggest that retrieval from long-term memory may be accomplished through a sequential search process or a spreading activation process. Some forgetting from long-term memory is due to a loss from storage, particularly when there is a disruption of the processes that consolidate new memories. The biological locus of consolidation includes the hippocampus and surrounding cortex. Recent research suggests that consolidation takes a few weeks to be completed.

11 Retrieval failures in long-term memory are less likely when the items are organized during encoding and when the context at the time of retrieval is similar to the context at the time of encoding. Retrieval processes can also be disrupted by emotional factors. In some cases, anxious thoughts interfere with retrieval of the target memory; in others, the target memory may be actively blocked (repressed). In still other cases, emotion can enhance memory, as in flashbulb memories. Explicit memory refers to the kind of memory manifested in recall or recognition, in which we consciously recollect the past. Implicit memory refers to the kind of memory that manifests itself as an improvement on some perceptual, motor, or cognitive task, with no conscious recollection of the experiences that led to the improvement. While explicit memory – particularly recall and recognition of facts – breaks down in amnesia, implicit memory is usually spared. This suggests that there may be separate storage systems for explicit and implicit memory. Research with normal individuals also suggests that there may be separate systems for explicit and implicit memory. Much of this research has relied on a measure of implicit memory called priming (for example, the extent to which prior exposure to a list of words later facilitates completing stems of these words). Some studies reveal that an independent variable that affects explicit memory (amount of elaboration during encoding) has no effect on priming, while other studies show that a variable that affects implicit memory has no effect. For more Cengage Learning textbooks, visit www.cengagebrain.co.uk CHAPTER SUMMARY on explicit memory. Brain-scanning studies with normal individuals show that explicit memory is accompanied by increased neural activity in certain regions whereas implicit memory is accompanied by a decrease in neural activity in critical regions. Unlike a videotape, a memory is constructed and reconstructed on the basis of expectations and knowledge: It shows systematic departures from the objective reality that underlies it. This kind of reconstruction can occur at the time the memory is originally formed, or at varying time periods following its formation. This kind of reconstruction forms the basis for memories that, while systematically incorrect, seem very real, and are recounted with a great deal of confidence. Although we cannot increase the capacity of working memory, we can use recoding

schemes to enlarge the size of a chunk and thereby increase the memory span. Long-term memory for facts can be improved at the encoding and retrieval stages. One way to improve encoding and retrieval is to use imagery, which is the basic principle underlying mnemonic systems such as the method of loci and the key-word method. Other ways to improve encoding (and subsequent retrieval) are to elaborate the meaning of the items and to organize the material during encoding (hierarchical organization seems preferable). The best ways to improve retrieval are to attempt to restore the encoding context at the time of retrieval and to practice retrieving information while learning it.

WEB RESOURCES <http://www.atkinsonhilgard.com/> Take a quiz, try the activities and exercises, and explore web links. <http://www.exploratorium.edu/memory/index.html> Think you have a good memory? Put it to the test on this site! You can also explore an interactive dissection of a sheep brain, which will help you see where memory processes take place. <http://human-factors.arc.nasa.gov/ihi/cognition/tutorials.php> This site, hosted by NASA, allows you to explore issues in cognitive psychology. There are interactive exercises involving recognition, recall, interference, and short-term memory.

<http://psych.athabascau.ca/html/aupr/cognitive.shtml#Memory> This website includes numerous links to memory-related resources online. CORE CONCEPTS encoding stage storage stage retrieval stage sensory store short-term memory rehearsal elaboration long-term store explicit memory implicit memory sensory memory span of apprehension partial-report procedure sensory response working memory phonological loop visual-spatial sketchpad memory span chunking flashbulb memory long-term memory amnesia constructive and reconstructive processes constructive memory encoding perceptual interference inferences post-event memory reconstruction schema stereotype social stereotype post-event information memory illusion source monitoring mnemonic system CHAPTER 8 MEMORY For more Cengage Learning textbooks, visit www.cengagebrain.co.uk

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