CHAPTER

5

Forming and Using New Memory Traces

Many cognitive psychologists regard memory as one of the most basic cognitive processes. We rely on memory whenever we think back to a personal event—when we remember, for example, our first day of school, our 10th birthday, or a trip to Disneyland. Memory is also obviously involved when we remember information about historical events, such as the *Challenger* explosion, the 9/11 attacks, or the sudden death of Diana, Princess of Wales. All these cases illustrate **retrieval,** the calling to mind of previously stored information. The processes by which we do so are the focus of this chapter and the next three chapters.

In one way or another, memory enters into almost every cognitive activity. Clearly, activities such as taking an exam or remembering the name of your third-grade teacher require memory. But other activities, such as balancing a checkbook or comprehending a sentence, also involve some aspect of memory. While doing the calculations necessary to balance a checkbook, we have to keep some numbers in mind, at least for a

moment. Similarly, when we hear or read a sentence, we have to keep the beginning of the sentence in mind while we process its middle and end. We use memory so frequently that, as with other cognitive processes, we tend to take it for granted.

Try, for example, to recall your first day at college. What do you remember about that day? Now ask yourself how you are able to recall any of these memories (if in fact you can). If you drew a total blank, why? What exactly goes on when you try to recall? What makes some information memorable and other information hard to recall? (For example, can you describe what your cognitive psychology professor wore two lectures ago?)

Sometimes we fail to notice how extraordinary a particular ability is until we encounter someone who lacks it. Baddeley (1990) has described the tragic case of Clive Wearing, a musician and broadcaster who, because of brain damage caused by encephalitis, has been left with severe amnesia. Although many people suffer from amnesia, Wearing's case is one of the most devastating on record. As Baddeley described it,

> His amnesia was so dense that he could remember nothing from more than a few minutes before, a state that he attributed to having just recovered consciousness. Left to his own devices, he would often be found writing down a time, for example, 3:10, and the note, "I have just recovered consciousness," only to cross out the 3:10 and add 3:15, followed by 3:20, etc. If his wife left the room for a few minutes, when she returned he would greet her with great joy, declaring that he had not seen her for months and asking how long he had been unconscious. Experienced once, such an event could be intriguing and touching, but when it happens repeatedly, day in, day out, it rapidly loses its charm. (pp. 4–5)

Interestingly, a few of Wearing's memory abilities seem to have been spared. He has apparently conducted a choir through a complex piece of music and can still play the harpsichord and piano. These abilities are the exception rather than the rule, however. Wearing cannot go out alone because he would quickly become lost and unable to find his way back. He cannot recognize much in photographs of familiar places, and his memories of his own life are quite sketchy.

In this chapter and the next, I will try to explain these phenomena. To do so, we will look in detail at the processes people use to form, store, and retrieve information. We will examine theoretical approaches to the study of memory, considering memory that lasts only briefly as well as memory that endures for hours, weeks, and even years. Much of the research described in Chapters 5 and 6 comes from the laboratory, where experiment participants, often college student volunteers, are presented with lists or series of words, syllables, or pictures under highly controlled conditions. In some parts of Chapter 6, we will consider how well laboratory-based models apply to memory phenomena outside the laboratory, most often to memories for episodes from people's own life stories.

A brief review of terminology is in order before we begin. We say that **encoding** occurs when information is first translated into a form that other cognitive processes can use. It is held in **storage** in one form or another for later retrieval. We say that **forgetting** occurs when we cannot retrieve information.

■ METAPHORS OF MEMORY

Fascination with what memory is and how it works has a long tradition in philosophy, predating any psychological investigations. Neath and Surprenant (2003) noted that the Greek philosopher Plato wrote about memory, comparing it both to an aviary and to a wax tablet on which impressions are made. Throughout the Middle Ages and Renaissance, other analogies were made between memory and a cave, an empty cabinet, and a body in need of exercise.

In the 1950s, memory was compared to a telephone system, and later it was compared to a computer. One theoretical approach to studying memory, which dominated cognitive psychology throughout the 1960s and 1970s, distinguishes among kinds of memory according to the length of time information is stored.

This **modal model of memory,** assumes that information is received, processed, and stored differently for each kind of memory (Atkinson & Shiffrin, 1968; Waugh & Norman, 1965). Unattended information presented very quickly is stored only briefly in **sensory memory.** Attended information is held in **short-term memory (STM)** for periods of up to 20 or 30 seconds. (Synonyms for STM include *primary memory* and *short-term storage,* or *STS.*) Information needed for longer periods of time—the correct spelling of the words on tomorrow's test, for example, or the name of your fourth-grade teacher—is transferred to **long-term memory (LTM),** sometimes called *secondary memory* or *long-term storage* (*LTS*). Figure 5-1 depicts an overview of the modal view of memory. We'll begin our look at psychological investigations of memory using this metaphor, largely because of its enormous influence on the field of cognitive psychology and its ability to make sense of a wide range of memory findings.

Many empirical findings seem to support the idea of different memory systems. One well-known finding comes from free-recall experiments, in which people are given a list of words to remember, such as that shown in Figure 5-2(A), and are asked to recall the words in any order. Next, the experimenter, using data from all the participants, computes the probability of

FIGURE 5-1 ■ *The modal view of memory. Each box depicts a memory storage system. The arrows represent the transfer of information between systems.*

SOURCE: Goldstein (1994, p. 278).

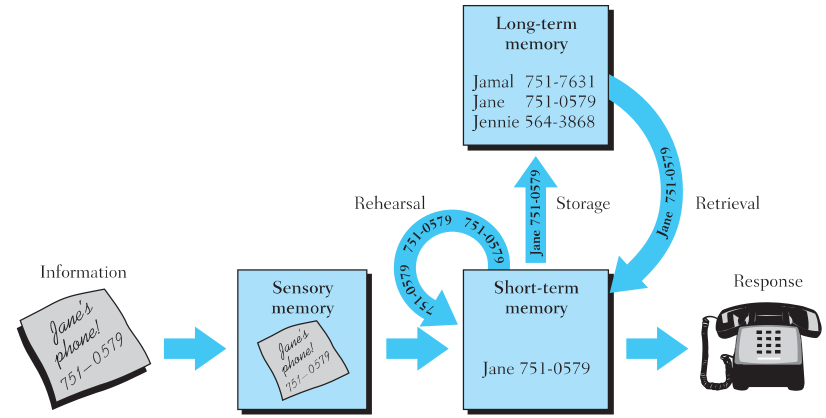
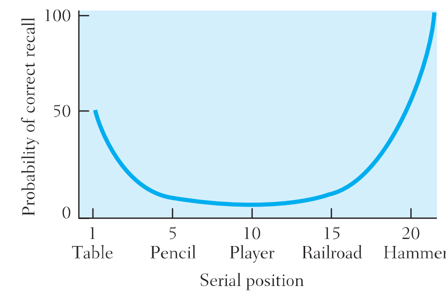


FIGURE 5-2 ■ *Word list for a serial position curve experiment (A); typical results (B).*

1 Table	11 Kitten
2 Candle	12 Doorknob
3 Maple	13 Folder
4 Subway	14 Concrete
5 Pencil	15 Railroad
6 Coffee	16 Doctor
7 Towel	17 Sunshine
8 Softball	18 Letter
9 Curtain	19 Turkey
10 Player	20 Hammer

(A)



(B)

recall of each word as a function of the word's serial position in the original list. In our example, *table* would be in serial position 1 because it is the first word on the list; *candle* is in serial position 2; and so forth. Figure 5-2(B) shows an idealized version of typical results (Murdock, 1962).

Notice that the two ends of the curve are higher than the middle, indicating that people recall more words at either the beginning or the end of the list than they do words in the middle. This is known as the **serial position effect.** The improved recall of words at the beginning of the list is called the **primacy effect;** that at the end of the list, the **recency effect.**

What accounts for these two effects? Participants typically report subvocalizing to themselves as follows when they first start the experiment:

EXPERIMENTER (*reading list at a fixed rate*): Table.

PARTICIPANT (*to self*): Table-table-table-table.

EXPERIMENTER: Candle.

PARTICIPANT (*a little faster*): Table-candle-table-candle.

EXPERIMENTER: Maple.

PARTICIPANT (*very rapidly*): Table-candle-maple-table-candle.

EXPERIMENTER: Subway.

PARTICIPANT (*giving up on rehearsing earlier words*): Subway.

We'll see later that the participant's repetition of items, or **rehearsal,** is thought to help the items enter long-term storage. In fact, if the experimenter reads the list rapidly enough to prevent the participant from having enough time to rehearse, the primacy effect disappears, although the recency effect stays intact (Murdock, 1962).

The recency effect is thought to result from participants' using either sensory memory or short-term memory. Participants often report that they can still "sort of" hear the last few words, and they often report these first and quickly. If the experimenter prevents the participant from reporting words right away, by having her first perform an unrelated counting task, the recency effect (but not the primacy effect) disappears (Postman & Phillips, 1965).

That the primacy and recency effects can be independently affected suggests they reflect two kinds of memory. In addition, some psychologists argue for a third kind of memory, sensory memory, which is thought to work differently from both the other systems. Those who endorse the idea of sensory memory believe that incoming information first passes through this rapidly decaying storage system. If attended to, the information next moves to STM. To be held for longer than a minute or two, the information must be transferred again, this time to LTM.

We will take up the first two hypothesized kinds of memory in this chapter, examining first sensory memory and then STM. After a look at the modal model and its predictions and explanations, we will focus on a newer proposal from psychologist Alan Baddeley, called *working memory.* Next we'll turn our attention to recent proposals for the existence and importance of

executive processes that govern and direct the operation of other cognitive processes, picking up on a discussion begun in Chapter 4. This chapter will conclude by looking at both neuropsychological evidence and recent connectionist models, developed on computers, of memory for material actively being processed. We'll defer until Chapter 6 discussion of memories stored over longer periods.

SENSORY MEMORY

Sensory "memory" is closely connected to what we call "perception." This kind of memory has been described as a record of our percepts (Baddeley, 1990), because it refers to the initial brief storage of sensory information—what you might retain, for example, if you glanced up quickly at a billboard and then glanced quickly away. In fact, there have been debates within cognitive psychology as to whether the findings from a typical sensory memory study are perceptual or memorial (relating to memory) in nature (Neath & Surprenant, 2003), although the more common view today is that the phenomena are in fact more like other memories than they are like other perceptions.

Many cognitive psychologists hypothesize that separate sensory memories exist for each sensory modality. In other words, they believe there is a visual sensory memory, an auditory sensory memory, an olfactory (pertaining to smell) sensory memory, a gustatory (pertaining to taste) sensory memory, and a tactile (pertaining to touch) sensory memory. The overwhelming bulk of the research on sensory memories to date has focused on the first two types of sensory memory, called the *icon* and the *echo,* respectively.

The Icon

Imagine sitting in a classroom equipped with an overhead projector. The lecturer enters and puts her first transparency on the projector. To check that it is working, she quickly clicks it on and off (she doesn't want to give anyone too much of a sneak preview). If you had been looking at the projection screen when the lecturer clicked the projector on and off, you might have experienced a rapidly fading visual event, and you might have thought it was due to a physical extinguishing of a stimulus—perhaps the bulb in the projector slowly fading. But more carefully controlled studies have demonstrated that the effect is a mental experience (Massaro & Loftus, 1996), as we shall see.

Sperling (1960) conducted an elegant experiment, now considered classic, to investigate the properties of visual sensory memory. He presented participants with displays containing letters, such as shown in Figure 5-3, and asked

FIGURE 5-3 ■ *Example of the kind of stimulus display used by Sperling (1960).*
SOURCE: Sperling (1960, p. 3).

S D F G

P W H J

X C V N

them to recall the letters they saw. The displays were presented briefly, for only 50 milliseconds. Sperling found that, on average, people could report only 4 or 5 of the 12 letters presented. Extending the display time, even to 500 milliseconds, did not improve performance. The problem wasn't perceptual; 500 milliseconds, or half a second, is plenty of time to perceive something about all the letters (Klatzky, 1980).

Sperling (1960) did find a way to improve participants' performance, however, inventing what has become known as the *partial-report technique*. After seeing the display, participants were presented with a low-, medium-, or high-pitched tone. A low pitch indicated they were to report only the letters in the bottom row of the display; a high pitch, those in the top row; and a medium pitch, those in the middle row. Regardless of which tone sounded, participants' reports were almost always completely accurate. This finding suggests participants must have stored the whole display, because they did not know ahead of time which tone would sound. If their accuracy on a randomly chosen row was, say, 90%, we can infer their accuracy for any row would have been 90%. In fact, Sperling found that with the partial-report technique, participants accurately recalled an average of about 3 out of 4 letters in any given row, suggesting an average total recall of about 75% or more.

What caused the better performance? Sperling believed that in the original condition (called the *whole-report condition* because participants had to report the whole display), participants lost the information in their memory during the time they took to report the first few letters. Put another way, even as participants were recalling the display, the information was fading from wherever it was being stored. This implies that information lasts only briefly in this memory system. In fact, Sperling found that if the tone was delayed 1 second, participants giving partial reports did no better than participants giving whole reports.

Neisser (1967) called this brief visual memory the **icon.** The icon is a sensory memory storage system for visual material, holding information for up to about 1 second. The information it holds is in a relatively unprocessed form,

as another of Sperling's (1960) experiments showed: If the displays contained both consonants and vowels, and if two different tones cued the participants to report either all the vowels or all the consonants, participants' performance roughly matched their performance when giving whole reports. That indicated that people are not so good at reporting by category (vowel or consonant) as they are at reporting by physical location (e.g., top row, bottom row). Therefore, Sperling inferred, the icon holds information that has not yet been categorized.

Averbach and Coriell (1961) showed that the icon can be "erased" by other stimuli presented immediately after the icon, a phenomenon known as *masking*. For instance, if the display with letters was followed by a display with circles, and if the participant was told to report which letters had been in the locations of the circles, the circles appeared to "erase" the memory trace of the letters originally shown.

Other work investigated how many ways participants could be cued to give partial reports (see Coltheart, 1980, for a review). Different investigators showed that such things as the color or brightness of the letters could be used to cue partial reports. Interestingly, cueing partial reports by category or phonological sound (for instance, "Report all the letters that rhyme with *B*") is all but impossible. This suggests the information available in the icon is only visual—not auditory or related to type of stimulus.

More recent work has complicated the picture of the icon described so far. Neath and Surprenant (2003) reviewed studies that did find evidence research participants could be successfully cued to report by category. They also described other studies showing that although information for the particular location in the matrix fades over time, information about *which* letters were presented does not seem to. As a result, some cognitive psychologists are now coming to view the icon as a mental representation lasting only about 150 to 200 milliseconds, followed by a recoding of the stimulus into another, more meaningful code.

The Echo

There is also a sensory memory for auditory material, which Neisser (1967) called the **echo.** Moray, Bates, and Barnett (1965) offered a clever demonstration of the echo. Participants were given a "four-eared" listening task, similar to a dichotic listening task (see Chapter 4 if you've forgotten what this is). They heard, simultaneously over headphones, four channels of incoming information, each apparently coming from a different location, consisting of a string of random letters. (The four channels were created by stereophonic mixing.)

In one condition, similar to Sperling's (1960) whole-report condition, participants were asked to report all the letters they had heard. In another condition, each participant held a board with four lights on it, each light corresponding to one of the channels, cueing the participant to report only the letters from a particular channel. As did Sperling, Moray et al. found that participants giving partial reports could report proportionately more letters. This suggests that the echo, like the icon, stores information only briefly.

Darwin, Turvey, and Crowder (1972) later replicated Moray et al.'s result, using better experimental controls, although they found a much smaller partial-report advantage. Darwin et al. also found that recall could be cued by category, at least to some degree, suggesting that the echo works somewhat differently from the icon. Crowder (1976), reviewing the literature on echoic memory, proposed that echoic memory has a larger capacity than iconic memory. Other investigations (Watkins & Watkins, 1980) provided evidence that echoes can last longer than icons, perhaps even as long as 20 seconds, although other researchers disagree with these conclusions (Massaro & Loftus, 1996).

A demonstration called the "suffix effect" also reveals something about the nature of echoic memory. Imagine you are a research participant in a memory experiment, and a list of random digits, letters, or the like is being presented to you. If the list is presented to you auditorily (as opposed to visually), and if there is an auditory recall cue such as a spoken word or specific item, recall of the last few items on the list is seriously hindered (Crowder, 1972).

Researchers think the recall cue, called the *suffix,* functions as an auditory "mask" of sorts, because when the suffix is simply a beep or tone, or a visual stimulus, there is usually not much effect. Nor is there any effect if the items on the list are presented visually—say, on a computer screen. Finally, the more auditory similarity there is between the suffix and the items on the list, the greater the suffix effect.

Although research continues to refine our understanding of both the icon and the echo, sensory memory can currently best be described by a number of properties. First, sensory memories are *modality specific:* the visual sensory memory contains visual information; the auditory sensory memory, auditory information; and so forth. Second, sensory memory capacities appear relatively large, but the length of time information can be stored is quite short, much less than a second. Third, the information that can be stored appears relatively unprocessed, meaning that most of it has to do with physical aspects of the stimuli rather than with meaningful ones.

Some proposals (Haber, 1983; Neisser, 1983) have disputed the idea that the icon and the echo play a necessary role in perception or memory. Although no one disputes the findings reported by Sperling (1960) and others, some

argue that problems arise with the interpretations of the findings. In particular, some researchers assert that the very brief (typically less than a second) presentation of stimuli created an artificial task for participants, unlike anything people would need or want to do outside the laboratory. In contrast, Neath and Surprenant (2003) argued that sensory memory research could have a very practical use outside the laboratory: Having directory assistance operators say "Have a nice day" after giving a phone number should (and apparently does) disrupt recall for the phone number because their pleasant sign-off acts as a suffix!

Another counterargument to the idea that sensory memory is only a laboratory phenomenon is that sensory memory guarantees a minimum of time during which information presented to us (that we pay attention to) is available for processing (Baddeley, 1990). In other words, by this argument sensory memory *does* play an important role in the everyday workings of normal memory: It ensures that we will be able to "reinspect" incoming data, if not with our actual eyes and ears, then with the mind's eye and the mind's ear. As you can see, then, the role that sensory memory plays in later processing of information is very much debated.

Lambert/Getty Images

Research on the echo suggests that telephone operators who wish callers a nice day may inadvertently be disrupting their auditory sensory memory of the phone number they've just provided.

■ SHORT-TERM MEMORY

Most of the time, when people think about memory they think about holding onto information for longer than a second or two. In the rest of this chapter and the next, we'll talk about kinds of memory more familiar to nonpsychologists.

We'll first look at STM. You use this kind of memory system when you look up a phone number, walk across a room to a telephone, and dial the number. Suppose I asked you to call one of my colleagues, whose phone number is 555-4362. Suppose further that you couldn't take this book with you but had to remember the number until you could dial it on a nearby phone. How would you accomplish this task? Chances are you'd begin by rehearsing the number aloud several times as you walked across the room. You'd dial the number, but as soon as the conversation started, you'd be likely to have forgotten the number you dialed. This example illustrates one aspect of STM: It lasts only a short while. (Cognitive psychologists typically regard STM as lasting for a minute or two, if rehearsal is not prevented; however, neuropsychologists sometimes consider information in STM as lasting for up to a day, which can lead to some confusion. When I talk about STM, I'll be talking about material stored for up to about a minute.)

Does any other distinguishing characteristic separate STM from LTM, other than length of time information is stored? Psychologists who make the distinction believe there are a number of such characteristics, including how much information can be stored (capacity), the form in which the information is stored (coding), the ways in which information is retained or forgotten, and the ways in which information is retrieved. How psychologists working within the information-processing paradigm conceptualize STM has changed a great deal over the past two decades. We'll begin with a look at the traditional description of STM before looking at a newer proposal of what has been renamed *working memory* to avoid confusion.

Capacity

If you are going to store information for only a short period of time (as in the phone number example), how much room do you have in which to do so? In other words, how much information can you remember for only a brief period of time? A classic paper by George Miller (1956) begins with the following rather unusual confession addressing these questions:

> My problem is that I have been persecuted by an integer. For seven years this number has followed me around, has intruded in my most private data, and has assaulted me from the pages of our most public journals. This number assumes a variety of disguises, being sometimes a little larger and sometimes a little smaller than usual, but never changing so much as to be unrecognizable.

> The persistence with which this number plagues me is far more than a random accident. There is, to quote a famous senator, a design behind it, some pattern governing its appearances. Either there really is something unusual about the number or else I am suffering from delusions of persecution. (p. 81)

The integer plaguing Miller was 7 (plus or minus 2). Among other things, 7 (plus or minus 2, depending on the individual, the material, and other situational factors) seems to be the maximum number of independent units we can hold in STM. We call this the **capacity** of STM.

Miller (1956) reviewed evidence demonstrating that if you are presented with a string of random digits, you'll be able to recall them only if the string contains about seven or fewer digits. The same is true if you are presented with random strings of any kinds of units: letters, words, abbreviations, and so on. The only way to overcome this limitation is by somehow **chunking** the individual units into larger units. For instance, consider the following string of letters: *N F L C B S F B I M T V.* This 12-letter string would normally exceed almost everyone's short-term memory capacity. But if you look closely at the letters, you'll see they really form four sets of abbreviations for well-known entities: *NFL* (the National Football League), *CBS* (one of the three major television networks currently operating in the United States), *FBI* (the Federal Bureau of Investigation), and *MTV* (the rock video cable television station). If you notice that the 12 letters are really four organized sets, you'll be more likely to recall the entire string. In recognizing that the three sets of letters really "go together" and in forming them into a single unit, you are said to be chunking them.

Chunking depends on knowledge. Someone not familiar with our culture might regard *MTV* as merely three randomly presented letters. Miller regarded the process of forming chunks (he called it "recoding") as a fundamental process of memory—a very powerful means of increasing the amount of information we can process at any given time, and one we use constantly in our daily lives. The process of chunking can be seen as an important strategy in overcoming the severe limitation of having only seven or so slots in which to temporarily store information.

Coding

The term **coding** refers to the way in which information is mentally represented—that is, the form in which the information is held. When you try to remember a phone number, as in the preceding example, how do you represent it? A study by R. Conrad (1964) addressed this question. He presented participants with lists of consonants for later recall. Although the letters were presented visually, participants were likely to make errors that were similar in *sound* to the original stimuli. So, if a *P* had been presented, and participants later misrecalled this stimulus, they were much more likely to report a letter that *sounded* like *P* (for example, *G* or *C*) than to report a letter that *looked* like *P* (such as *F*). Remember, the original presentation was visual, but participants apparently were confused by the sound. Participants were apparently forming a mental representation of the stimuli that involved acoustic rather than the visual properties.

Later work by Baddeley (1966a, 1966b) confirmed this effect even when the stimuli were words rather than letters: Similar-sounding words make for poor immediate recall, although similar-meaning words don't, and the reverse is true for delayed recall. Although an acoustic code is not the only one used in STM, researchers have regarded it as the dominant code used, at least by hearing adults and older children (Neath & Surprenant, 2003).

Retention Duration and Forgetting

We regard STM as the storage of information for short periods of time. But how short is short? John Brown (1958) and Peterson and Peterson (1959), working independently, came to the same conclusion: If not rehearsed, information is lost from STM in as little as 20 seconds. That length of time is called the **retention duration** of the memory.

The Brown–Peterson task works as follows. Participants are presented with a three-consonant trigram, such as *BKG*. They are also given a number, such as 347, and asked to count backward out loud by threes, at the rate of two counts per second, in time to a metronome. The purpose of the counting task is to prevent the participant from rehearsing the trigram. The length of time a participant must count varies. If asked to count backward for only 3 seconds, roughly 80% of participants can recall the trigram. If asked to count for 18 seconds, this drops to about 7%. Both Brown and the Petersons interpreted this finding as meaning that the **memory trace**—the encoded mental representation of the to-be-remembered information that is not rehearsed—**decays,** or breaks apart, within about 20 seconds. Putting this interpretation into our phone number example gives us the following: If I tell you my phone number, and you fail to do something to remember it (say, by rehearsing it or writing it down), you'll be able to remember it only for a maximum of about 30 seconds. After that time, the memory trace will simply decay, and the information will be lost.

However, other cognitive psychologists soon began to challenge this decay explanation of forgetting. They proposed a different mechanism, called **interference,** that worked as follows: Some information can "displace" other information, making the former hard to retrieve. You can think of the interference explanation as being akin to finding a piece of paper on my desk. At the start of each academic term, my desk is (relatively) free of clutter. Any piece of paper placed on the desktop is trivially easy to find. However, as the term goes on and my time grows short, I tend to allow all kinds of memos, papers, journals, and

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A photo of my desk, representing the idea of memorial interference.

the like to accumulate. Papers placed on my desk at the beginning of the term become buried; they're there, all right, but can be very difficult to find at any given moment. The late-arriving papers have "displaced" the early papers.

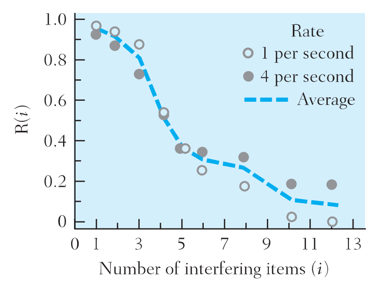
Can we explain the Brown–Peterson task results in terms of interference? Think once again about the counting task. Notice that it supposedly has very little purpose other than to distract the participant from rehearsing the trigram. Yet maybe the counting task does more than prevent participants from rehearsing; it may actually interfere with their short-term storage of the trigram. As participants count aloud, they compute and announce the values. As they compute and announce the values, they put them into STM. Thus the counted values may actually be displacing the original information.

A study by Waugh and Norman (1965) demonstrated the role of interference in STM. They invented the *probe digit task,* which works as follows. Participants are given a 16-digit number, such as 1596234789024815. The last digit in the number is a cue for the participant to report the number that first came after the first occurrence of the cue in the number. (It's a little complicated to follow that instruction, but it can be done; stop reading for a moment and actually try it.) In our example, the cue is 5 (it's the last digit of the number), and the first occurrence of 5 in the number is followed by a 9, so the response should be 9.

Waugh and Norman (1965) presented the numbers either quickly, at the rate of four digits per second, or slowly, at the rate of one digit per second. Their reasoning was that if decay caused forgetting in STM, then participants receiving a slow rate of presentation should be not as good at recalling digits from early in the number. This is because more time would have elapsed on trials with the slow presentation, causing more decay from the beginning of the number. Figure 5-4 (which plots the rate of recall as a function of the number of interfering items) shows, however, that this is not what happened. Participants showed equivalent performance on recalling digits throughout the number regardless of rate of presentation. On all trials, participants were not as good at recalling digits from early in the number as from later in the number, implicating interference rather than decay in forgetting information in STM.

FIGURE 5-4 ■ *Results from Waugh and Norman's (1965) probe digit task study.*

SOURCE: Waugh and Norman (1965, p. 91).



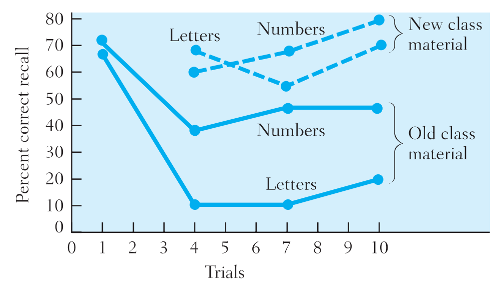
Other evidence also supported the view that interference, not decay, accounts for forgetting in STM. Keppel and Underwood (1962), for instance, found that forgetting in the Brown–Peterson task doesn't happen until after a few trials. They suggested that over time, **proactive interference** builds up. This term refers to the fact that material learned first can disrupt retention of subsequently learned material. (We'll discuss this phenomenon in greater detail in Chapter 6.) Keppel and Underwood showed that even one trial's worth of practice recalling a three-letter trigram was enough to hurt subsequent memory for other trigrams.

Wickens, Born, and Allen (1963) extended the idea one more step. They reasoned as follows: If STM, like LTM, is subject to proactive interference, then STM, like LTM, should also be subject to a related phenomenon, *release from proactive interference*. In other words, if you learn a number of pieces of similar information, after a while any new learning becomes more difficult because the old learning interferes with the retention of new (because of proactive interference). The greater the similarity among the pieces of information, the greater the interference. This implies that if a new and very distinct piece of information were presented, the degree of interference would be sharply reduced.

Wickens et al. (1963) demonstrated release from proactive interference in a clever experiment. They gave participants a series of either three-digit strings (such as *179*) or three-letter strings (such as *DKQ*). There were 10 trials in all. Some participants received 10 trials of the same type (that is, all-letter strings or all-digit strings). Others saw a "switch" in the stimuli partway through the 10 trials. For example, a person might see 3 trials with letters but then be switched to seeing digits on all subsequent trials. Figure 5-5 shows the results. Participants getting a "switch" performed almost as well immediately after the switch as they did on the first trial. Their memory is said to have been released, or freed, from the clutches of proactive interference!

FIGURE 5-5 ■ *Results from the Wickens et al. (1963) study on release from proactive interference in short-term memory.*

SOURCE: Wickens et al. (1963, p. 442).



All this evidence might lead you to think all cognitive psychologists agree that only interference causes forgetting in STM. The picture, however, is not that neat. Reitman (1971, 1974) initially offered evidence supporting an interference explanation of forgetting in STM. Her participants performed a Brown–Peterson task while simultaneously working on what was supposed to be a noninterfering task: detecting a syllable such as "doh" in a spoken stream of repetitions of a similar syllable ("toh"). The auditory detection task was supposed to prevent participants from rehearsing the trigram but not to interfere with material stored in STM. An interference account of forgetting in STM would predict no loss of the trigrams over the retention periods, and this is indeed what Reitman (1971) found. However, in an important follow-up, Reitman (1974) found that some of her participants confessed to "cheating" a bit: surreptitiously rehearsing the letters while they performed the detection task. When Reitman looked only at the performance of the participants who hadn't been rehearsing, she found clear effects of decay: Only 65% of the trigrams were retained after a 15-second interval. From this, Reitman concluded that information really could decay if not rehearsed in STM.

Reitman's research leaves us with an unresolved issue: What causes forgetting in STM, trace decay or interference? We cannot rule out either one, at least for now. One problem is that it is hard to think of a task in which no interference can occur. Thus, designing a definitive experiment (or series of definitive experiments) is beyond our current capabilities.

Also, maybe the question "Is it decay or is it interference?" is badly posed, because it rules out the possibility that both may be involved. That is, maybe STM loses information by more than one mechanism. Either/or questions exclude this possibility. Baddeley (1990) argues that some (although very little) trace decay does occur in STM along with interference. Altmann and Gray (2002) propose that decay does occur and in fact is essential to avoid catastrophic proactive interference. These authors believe that when information must be updated frequently in memory (example: you are driving and have to remember the speed limit on each new road you take), its current value (you're on an interstate, going 70 mph) decays to prevent interference with later values (you get off the highway, and the speed limit is now 55 mph).

Retrieval of Information

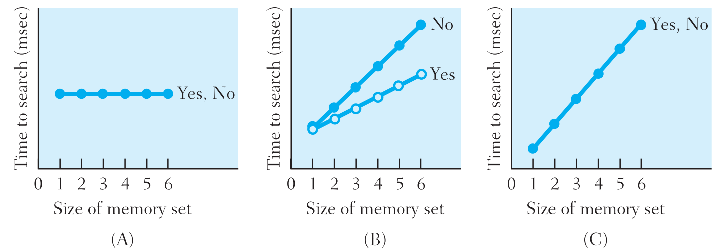
We've talked about the ways in which people hold onto information for brief periods of time: how they encode it, how much they can encode, and how long they can retain it. That brings us to the question "How do we retrieve this information from STM when we need it again?" Saul Sternberg (1966, 1969), in a series of experiments, found some surprising things about how we retrieve information from short-term memory. Before turning to his experiments, let's consider various possibilities of how information might be retrieved from STM.

Sternberg's first question was whether we search for information held in STM in a *parallel* or a *serial* manner. Imagine, for example, that STM is full of some (small) number of movie titles. Let's say STM holds a list of my all-time

favorite movies, which I have just orally given you. Let's call the number of movie titles the *memory set size.* Now suppose that someone asks you if *Titanic* is on that list and that to answer the question, you mentally search the list.

If you compare *Titanic* simultaneously to all the titles on your list, you are performing a **parallel search.** Essentially, no matter what the number of titles is, you examine them at the same time, and it takes you no more time to compare *Titanic* to 1 title than to 10 titles. Figure 5-6(A) depicts how the data would look if you used parallel search, plotting time to search against memory set size.

FIGURE 5-6 ■ *Theoretically predicted results from the Sternberg (1966) short-term memory-scanning experiment. "Yes" and "No" refer to whether the subject will report finding the probe letter in the memory set. (A) depicts a parallel search; (B), a serial, self-terminating search; (C), a serial, exhaustive search. The data that Sternberg reported looked most like those in (C).*



Suppose, instead, that you use a **serial search.** In our movie titles example, this would mean comparing *Titanic* to the first movie title on the list, then to the second title on the list, and so on, until you come to the last title. The comparisons are done one at a time. In this model, the longer the list is, the longer it should take to decide if *Titanic* matches a title on that list. Successful searches are indicated by the "yes" line; unsuccessful searchers (where a target is not found) by the "no" line.

We can also ask whether the search is self-terminating or exhaustive. A **self-terminating search** stops when a match is found. Suppose the list of movie titles is *Shopgirl, Memento, Titanic,* and *Jarhead.* If you do a self-terminating search, you will stop after the third comparison because you've found a match. On average, then, successful searches take less time (because you don't continue searching after you've found the match) than unsuccessful searches (where you have to search through everything). Figure 5-6(B) depicts the results we should see if retrieval from memory uses serial, self-terminating search.

Another kind of serial search is an **exhaustive search,** meaning that even if a match is found, you continue looking through every other item in the set. In our example, this would mean that even after you find *Titanic,* you check the remaining titles on the list. With this kind of search, it takes just as long for successful as for unsuccessful searches. Figure 5-6(C) shows this possibility.

Sternberg's (1966) experimental task was the following. First, participants were presented with a set of seven or fewer letters. These were to be encoded and held in short-term memory and hence could be called the "memory set." After the participant had the set in memory, he indicated readiness for an upcoming trial. A single letter, called a probe, was presented, and the participant's task was to decide, as quickly as possible, whether the probe was in the memory set. For example, the memory set might be *B K F Q,* and probes might be *K* (yes, in the memory set) and *D* (no, not in the memory set).

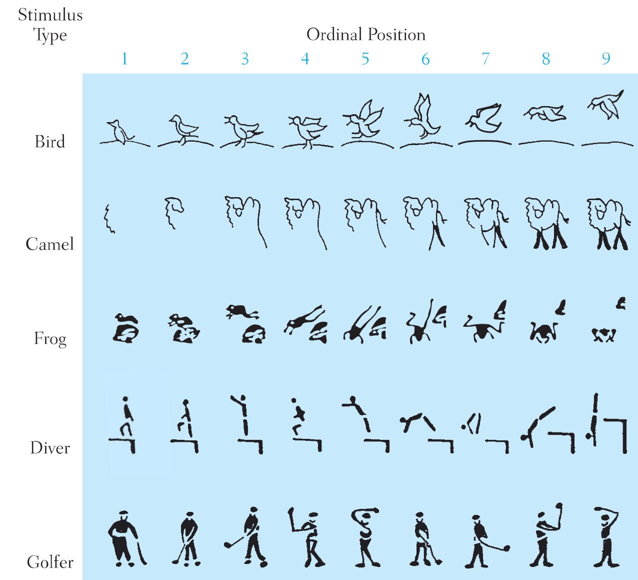
As counterintuitive as it sounds, Sternberg's (1966) results argue for serial, exhaustive search as the way we retrieve information from STM. Sternberg's explanation is that the search process itself may be so rapid and have such momentum it is hard to stop once it starts. From a processing point of view, it may be more efficient just to let the search process finish and then make one decision at the end, instead of making several decisions, one after each item in the memory set. A review by Hunt (1978) found that people of all sorts (college students, senior citizens, people with exceptionally good memories, retarded people) showed results consistent with the idea that retrieval from STM uses serial, exhaustive search, although search rate changes with the group, being faster for people with exceptional memories and slower for senior citizens.

As with just about any scientific proposal, later work by other investigators turned up problems with Sternberg's (1966, 1969) proposal of serial, exhaustive search. Baddeley (1976) reviewed some of the problems and alternative explanations of Sternberg's findings. An intriguing twist on the Sternberg study comes from DeRosa and Tkacz (1976), who demonstrated that with certain kinds of stimuli, such as those shown in Figure 5-7, people apparently search STM in a parallel way.

Note that the stimuli DeRosa and Tkacz used consisted of ordered sequences of pictures, such as pictures of a golfer executing a golf swing. If on the one hand the memory set consisted of some randomly selected subset of the nine pictures—for example, pictures 1, 4, 6, 8, and 9—from any of the sets, then the results looked like the typical Sternberg results. On the other hand, if the memory set consisted of an ordered subset of the original sequence—for instance, pictures 2, 3, 4, 5, and 6—then it took participants no longer to search through five items than it did through two. Interestingly, it didn't matter whether the ordered subset was presented in order (for example, picture 2, then picture 3, then picture 4, and so on) or not in order (say, picture 5, then picture 2, then picture 6, and so on); participants still apparently performed a parallel search.

FIGURE 5-7 ■ *Stimuli used by DeRosa and Tkacz (1976).*

SOURCE: DeRosa and Tkacz (1976, p. 690).



This work suggests that STM treats ordered, organized material differently from unorganized material. Just as the chunking of digits or letters into more coherent patterns changes the apparent capacity of STM, using organized material also apparently affects the way it is processed.

This study makes an important point: Memory processes apparently work differently as a function of the material (stimuli) to be remembered. Therefore, we cannot automatically generalize results from the laboratory to everyday life. Instead, to know which laboratory models bear on which kinds of phenomena we need to consider what kinds of information are processed in what ways.

Let's summarize our review of the STM system so far. The general picture that emerged in the 1960s and 1970s was that STM is a short-term, limited-capacity storehouse where information is coded acoustically and maintained through rehearsal. Information can be retrieved from this storage using high-speed, serial, exhaustive search. The nature of the information in STM, however, can help change the capacity and processing of stored information.

■ WORKING MEMORY

The idea that memory consists of a number of information-processing stores was most completely described by Atkinson and Shiffrin (1968). These authors distinguished between the information being stored, calling this "memory" (for example, STM, LTM), and the structure that did the storing, which they termed a "store" (for example, STS, LTS). Their conception of STS was that it does more than merely hold onto seven or fewer pieces of information for a few seconds. In addition, they thought, information in STS somehow activates relevant information from LTS, the long-term store, and gathers some of that information into STS. They equated STS with consciousness and saw it as the location of various *control processes* that govern the flow of information, such as rehearsal, coding, integration, and decision making. STS is involved in transferring information to LTS, in integrating various pieces of information, and in keeping certain information available.

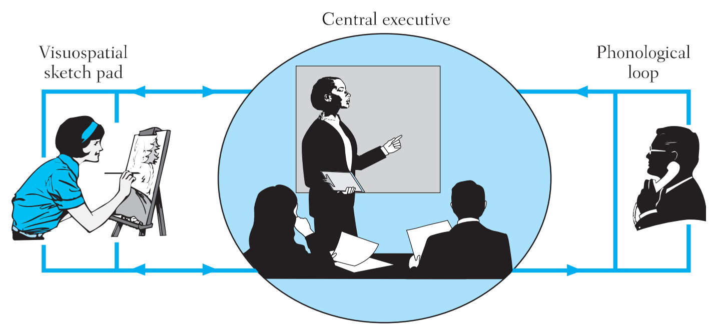
Baddeley and Hitch (1974) performed a series of experiments to test this model. The general design was to have participants temporarily store a number of digits (thus absorbing some of the STS storage capacity) while simultaneously performing another task, such as reasoning or language comprehension. These tasks were also thought to require resources from STS—specifically, the control processes mentioned earlier. The hypothesis was that if the STS capacity is taken up by stored digits, fewer resources are available for other tasks, so performance on other tasks suffers.

Let's look at one of Baddeley and Hitch's studies in detail. Participants saw a sentence describing the order of appearance of two letters—for example, "*A* is preceded by *B*"—together with two letters in a particular order—for example, "*B A*." The task was to decide, as quickly as possible, if the sentence correctly described the two letters. Participants were given from one to six digits to hold in memory while they verified the sentences. The results showed that participants were able to verify the sentences while holding one or two digits in memory about as well as they could without holding any digits in memory. However, a six-digit memory load did hurt performance: The sentence took longer to verify. The effect was especially pronounced if the sentence was negative and passive (for example, "*B* is not preceded by *A*"), both of which properties are known to be harder to process. Although performance was hurt by storing six digits, the effects were not catastrophic (Baddeley, 1990). That is, it took people much longer to reason while rehearsing six digits, but they still could perform the task. According to the predictions from Atkinson and Shiffrin's (1968) model, they should not have been able to do so. Related experiments showed that storing digits in memory also interfered with reading comprehension and the recall of recently learned material.

Baddeley and Hitch (1974) and Baddeley (1981) interpreted the findings from the various studies as follows. First, a common system does seem to contribute to cognitive processes such as temporarily storing information, reasoning, and comprehending language. Filling up STM with six digits does hurt performance on a variety of cognitive tasks, suggesting that this system is used in these tasks. However, the memory loads used, thought to be near the limit of STM capacity, do not totally disrupt performance. Because researchers think STM has a capacity of about seven items, plus or minus two, the six-digit memory load should have essentially stopped any other cognitive activity. Baddeley and Hitch (1974) therefore argued for the existence of what they called **working memory (WM).** They see WM as consisting of a limited-capacity "workspace" that can be divided between storage and control processing.

Baddeley (1981, 1986, 1990) conceived of WM as consisting of three components, as depicted in Figure 5-8. The first is the **central executive.** This component directs the flow of information, choosing which information will be operated on when and how. Researchers assume it has a limited amount of resources and capacity to carry out its tasks. Some of this capacity can be used to store information. The central executive is thought to function more as an attentional system than a memory store (Baddeley, 1990), meaning that rather than dealing with the storage and retrieval of information, the central executive deals with the way resources are allocated to cognitive tasks. So the central executive would be the system that controls many of the phenomena reviewed in Chapter 4. The central executive is also thought to coordinate information coming from the current environment with the retrieval of information about

FIGURE 5-8 ■ *Baddeley's (1990) model of working memory.*
SOURCE: Adapted from Baddeley (1990).



the past, enabling people use this information to select options or form strategies. Baddeley (1993a) equated this coordination with conscious awareness.

The two other components of Baddeley's model are concerned with the storage and temporary maintenance of information: the **phonological loop,** used to carry out subvocal rehearsal to maintain verbal material, and the **visuospatial sketch pad,** used to maintain visual material through visualization. Researchers think the phonological loop plays an important role in such tasks as learning to read, comprehending language, and acquiring vocabulary. The visuospatial sketch pad involves the creation and use of mental images.

Notice that postulating the existence of a separate phonological loop explains why having a person remember digits (which presumably loads the phonological loop) does not totally devastate performance on other tasks requiring WM. Researchers think this is so because the tasks spared are drawing on another part of working memory. Investigators think the phonological loop consists of two structures: a short-term phonological buffer (which holds onto verbal information for short periods of time, such as a few minutes, assuming rehearsal is not prevented), and a subvocal rehearsal loop used to compensate for the rapid decay of information in the phonological buffer (Demetriou, Christou, Spanoudis, & Platsidou, 2002). The idea here is that when the person initially encounters information, particularly verbal information, she translates it into some sort of auditory code and processes it through the phonological loop. Because the information from the phonological buffer decays rapidly, the person must subvocally rehearse the information, and the faster the rehearsal process, the more information can be maintained. If the phonological buffer is "filled up"—say, by having a person repeat a syllable or count aloud—then less capacity from this system is available to devote to other tasks.

Researchers have devised various working-memory-span tasks involving the phonological loop. A very well known one, created by Daneman and Carpenter (1980), works like this: A person is given a set of sentences to read (usually aloud)—but at the same time is asked to remember the last word in each sentence for later recall. For example, the participant might be presented with the following three sentences:

> The leaves on the trees turn various hues in autumn.
>
> A group of students congregated outside the front entrance of the delicatessen.
>
> Although lying and fabrication are generally not acceptable, they are sometimes necessary.

After reading them aloud, the participant is cued to recall the last word in each sentence. In this example, the correct answers are *autumn, delicatessen,* and *necessary.* The number of sentences a participant can process and reliably recall words from is said to be a measure of his span. This measure has been shown

to correlate significantly with other cognitive measures, such as reading comprehension and other complex cognitive tasks (Miyake, 2001).

The visuospatial sketch pad is to visual material as the phonological loop is to auditory and/or verbal material: Researchers think it maintains and is involved in the manipulation of visual information and imagery (Baddeley & Andrade, 2000). We will be taking up the topic of visual imagery in Chapter 9, and so will defer a detailed discussion until then.

Teasdale et al. (1995) reported an interesting application of Baddeley's conception of working memory. They focused on stimulus-independent thoughts (SITs), which they defined as "a flow of thought or images, the contents of which are quite unrelated to immediate sensory input" (p. 551). SITs include things such as daydreams or even intrusive thoughts such as when we worry or ruminate over a problem or concern.

Teasdale et al. (1995) questioned whether the production of SITs could be disrupted by having research participants perform another task. Some of the tasks they had their participants perform were verbal and were thought to involve the phonological loop of working memory. An example is the "silly sentences" task, in which people view a sentence (such as "Bishops can be bought in shops") and judge as quickly as possible whether each sentence is true or false. Other tasks were more visual or spatial. For example, people viewed complex drawings and were asked to find "hidden" geometric figures or to tap different keys on a keyboard in a particular manner.

During the experimental sessions, participants were stopped at different points and asked to tell the experimenter "exactly what was passing through [their] mind when [they] heard the experimenter say 'stop.'" Experimenters transcribed and later categorized these thoughts as to whether they pertained to the task at hand or were unrelated to it (that is, were SITs). Teasdale et al. (1995) found that both the auditory and the visuospatial tasks significantly disrupted SIT production. Thus neither the phonological loop nor the visuospatial sketch pad is solely responsible for SITs production.

In subsequent experiments, Teasdale et al. (1995) determined that producing these intrusive thoughts involves the central executive. They had research participants practice either a spatial task (keeping a light beam in a pencil-like instrument focused on a revolving circle; this is called a *pursuit rotor task*) or a memory task (keeping a specific digit in mind when the specific digit changed every 4 seconds). Next all participants performed both tasks and were again interrupted at various points and asked to report their thoughts. The researchers found that whichever task had been practiced produced far less interference with SITs than did the unpracticed task. In other words, when you or I perform a novel and challenging task, we are far less likely to experience intrusive, unrelated thoughts (for example, about the fight we just had with our partner, or about a dream vacation we hope to take someday) than if we are working at a task at which we are well practiced.

Note the fit of this explanation with the topics we discussed in Chapter 4. Presumably, tasks that have been practiced require less attention, or, in Baddeley's terminology, require fewer resources from the central executive of working memory. That capacity is thus available for the mind to do other things—for instance, to think about unrelated things. Unpracticed, demanding tasks, in contrast, "soak up" more central executive resources, leaving them unavailable to produce unrelated intrusive thoughts.

Teasdale et al. (1995) pointed out a practical implication of their research. Suppose you want to stop worrying about an issue. Tasks in which you simply repeat memorized phrases or chant the same word or phrase over and over again are not likely to be very effective, because they don't require enough of your central executive resources to block out the worrisome thoughts. Instead, Teasdale et al. proposed that you engage in a task in which you need to "make continuous demands on the control and coordinating resources of the central executive" (p. 558). One suggestion is to try to generate a word or phrase at random intervals, which requires you to continuously monitor your performance and coordinate your current response with your past responses.

Baddeley (1992) regarded his proposal about working memory as an evolution of the STM idea, rather than a competing proposal. Moving away from a view of STM as a passive, temporary, limited-capacity storehouse, Baddeley and others are now investigating the active role played by the processing system that is operating on current information and are separating this function from the temporary storage of information. Working memory is thought to be involved in translating visual information into an acoustic code, forming chunks, rehearsing to keep attention focused on material to remember (as in the phone number example, earlier), and sometimes elaborating incoming information by calling up relevant knowledge from LTM. Thus the term *working memory* conveys more than a temporary storehouse; rather, it connotes a place where the person exerts active mental effort to attend to, and often to transform, the material.

Indeed, Baddeley believes that WM supports conscious functioning, and that it

> has evolved as a means of allowing the organism to consider simultaneously a range of sources of information about the world, and [to use] these processes to set up mental models that facilitate the prediction of events and the planning of action. Consider, for example, the task of a hunter-gatherer who recollects that at this time of year a tree bears fruit near a waterfall in potentially hostile territory. In order to reach the tree safely, he may need to use remembered spatial cues, together with the sound of the waterfall and the shape of the tree, while listening and looking for signs of potential enemies. A dynamic image that is capable of representing these varied sensory features simultaneously is likely to provide a planning aid of considerable evolutionary value. (Baddeley & Andrade, 2000, p. 128)

EXECUTIVE FUNCTIONING

Recall from Chapter 4 the finding that in a dichotic listening tasks, people with higher working-memory (WM) capacity are *less* likely to detect their names in the unshadowed message (Conway, Cowan, & Bunting, 2001). A variety of other studies, reviewed by Engle and colleagues (Barrett, Tugade, & Engle, 2004; Engle, 2002; Unsworth & Engle, 2005), show other individual differences as a function of WM capacity on very different tasks.

One task studied by Kane, Bleckley, Conway, and Engle (2001) is called an "antisaccade" task. Research participants sit before a visual display and are asked to fixate their eyes in the middle of the screen. Then a stimulus (a letter to identify) is presented briefly on one side or the other of the screen, forcing the participant to attend to that stimulus in order to make the proper response as quickly as possible. Now, just before that stimulus is presented, the experimenters flash a cue of some sort. Sometimes this cue is presented on the same side of the screen the stimulus will appear on. The authors call this the "prosaccade" task, because the cue presumably causes the participant to automatically look at (by moving his eyes sideways with a saccade) the correct side of the visual display. In this condition, no differences appeared in reaction time to identify the target letter for participants with either very high WM capacity or very low WM capacity.

However, large differences arose in performance between high-WM and low-WM capacity in the *antisaccade* task, in which a cue appeared on the opposite side of the screen from where the target would appear. To perform optimally at this task, the research participant had to resist the temptation to have his attention drawn to the misleading cue. Now, this is a tough temptation, and everyone shows slower reaction time in this condition, relative to the prosaccade condition. However, the performance of low-WM-capacity participants was hurt more than that of high-WM-capacity participants.

In another study, Kane and Engle (2000) showed that low-WM-capacity individuals were more susceptible than high-WM-capacity individuals to the effects of proactive interference. However, when participants were given a second task, high-WM-capacity participants showed the same level of proactive interference as did low-WM-capacity participants. Engle (2002) believes that under normal conditions, high-WM individuals control their attention to resist the effects of proactive interference. In interpreting this set of results,

> my sense is that WM capacity is not about individual difference in how many items can be stored per se but about differences in the ability to control attention to maintain information in an active, quickly retrievable state. . . . WM capacity is not directly about memory—it is about using attention to maintain or suppress information . . . greater WM capacity also means greater ability to use attention to avoid distraction. (Engle, 2002, p. 20)

Other researchers have also found correlations between WM capacity and the ability to reason from premises, a topic we will consider in Chapter 12 (Markovits, Doyon, & Simoneau, 2002), and the ability to overcome the effects of postevent misleading information in an eyewitness memory task, a topic discussed in Chapter 7 (Jaschinksi & Wentura, 2002). Indeed, some authors link WM capacity to general fluid intelligence, a topic we'll explore in more depth in Chapter 15 (Suess, Oberauere, Wittman, Wilhelm, & Schulze, 2002).

We have seen a lot of growth and evolution of the concept of STM into WM. It makes sense to pause here and consider the key differences between the two concepts. Cowan (1995), Engle (2002), and Kail and Hall (2001), among others, have presented strong empirical evidence and theoretical arguments to suggest that STM and WM are distinct. STM can be thought of as information that is actively being processed, perhaps even information from long-term memory that is currently activated. WM included these active memory traces *as well as* the attentional processes used to maintain that activation and to keep the person focused on the primary cognitive task at hand.

In terms of the diagram in Figure 5-1, we can describe the development of the WM concept as the articulation of different STM components. Instead of regarding STM as a single entity, we are conceptualizing it in a new way and giving it a new name to indicate that it includes several components and is involved in a variety of forms of cognitive processing.

■ NEUROLOGICAL STUDIES OF MEMORY PROCESSES

Memory processes ultimately are instantiated in the brain, of course, and we will pause now to consider some relevant background and findings from the study of neuropsychology. Previous discussion of "stores" or "components" of memory can make it seem as if memory were located in one place in the brain—a sort of neural "filing cabinet" that holds onto memory traces of information being stored.

Actually, however, the picture emerging from neuropsychological studies is quite different and much more complicated. Memories don't all seem to be "stored" in one place. Desimone (1992) noted that in humans and animals, lesions of the cerebellum, a motor control structure, impair the acquisition of classically conditioned motor responses; lesions or disease of portions of the striatum, which normally functions in sensorimotor integration, impair stimulus–response learning of habits; lesions of the inferior temporal cortex, an area important for visual discrimination, impair visual recognition and associative memory; and lesions of the superior temporal cortex, an area important for auditory discrimination, impair auditory recognition memory.

> The medial temporal lobe is a major site of multimodal convergence, and it contains neurons that are sensitive to the configuration of many environmental stimuli as well as to the behavioral context in which events occur; thus it is not surprising that this region is critical for forming long-term explicit memories. (p. 245)

Much of the interest in "localizing" memory in the brain dates back to a famous case study. In 1953, William Beecher Stover, a neurosurgeon, performed surgery on H.M., a 27-year-old epileptic patient. Before the operation, H.M. was of normal intelligence. Stover removed many structures on the inner sector of the temporal lobes of both sides of H.M.'s brain, including most of the hippocampus, the amygdala, and some adjacent areas (see Figures 5-9 and 5-10). This noticeably reduced H.M.'s seizures, and H.M.'s postoperative IQ actually rose about 10 points (Schacter, 1996).

Unfortunately, however, H.M. suffered another decrement: He lost his ability to transfer new episodic memories into long-term memory, and thus became one of the most famous neuropsychological case studies in the literature. H.M. could remember semantic information (see Chapter 7 for a fuller discussion), and events that he had experienced several years before the operation.

FIGURE 5-9 ■ *Subcortical structures of the brain.*
SOURCE: Goldstein (1994, p. 89).

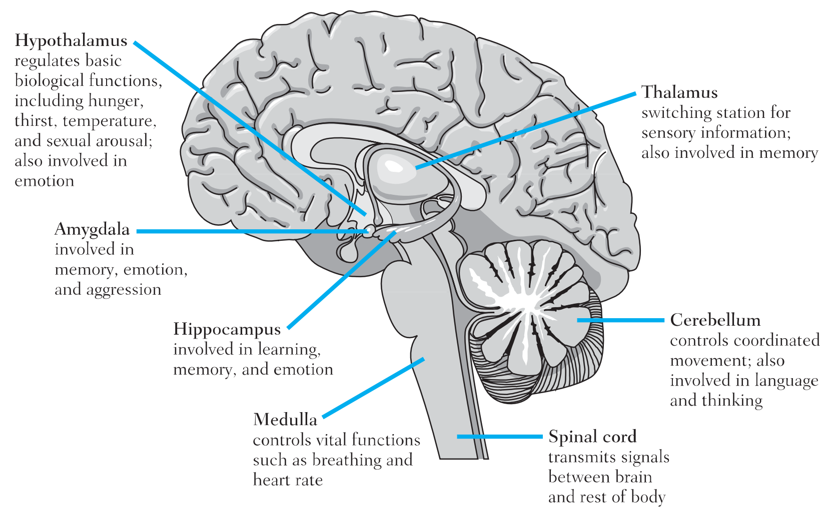
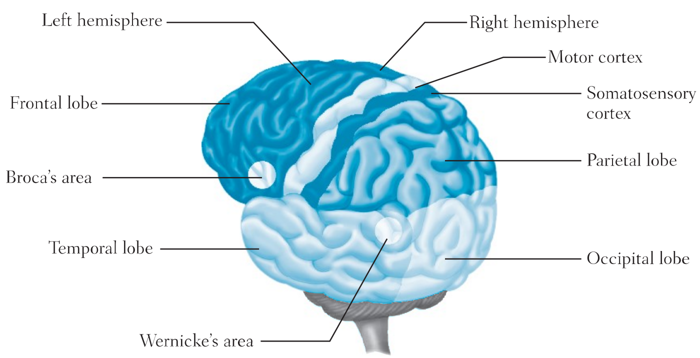


FIGURE 5-10 ■ *The cerebral cortex. The cerebral cortex is divided into two hemispheres, left and right, and each hemisphere can be divided further into four parts, or lobes.*

SOURCE: Nairne (1997, p. 89).



However, H.M. could no longer form new memories of new events. He could remember a series of seven or so digits, as long as he was not distracted, but if he turned his attention to a new task, he could not seem to store that (or much other) information. In addition to this **anterograde amnesia** (amnesia for new events), H.M. had **retrograde amnesia** (amnesia for old events) for the period of several years just before his operation.

H.M.'s case, widely publicized by psychologist Brenda Milner in the hope of preventing similar surgeries this extensive, suggested strongly that the structures removed from his brain, especially the rhinal cortex and underlying structures, played a major role in forming new memories. Other researchers reported other case studies and other animal studies that seemed to provide corroborating evidence.

H.M.'s case was also taken as evidence to support the distinction between long-term (perhaps very long-term) memories, which seemed accessible, at least for events several years before the operation, and short-term memories, which seemed unstorable. As we will see in Chapter 7, this statement seems to work only for certain kinds of memories, so the picture is a bit more complicated.

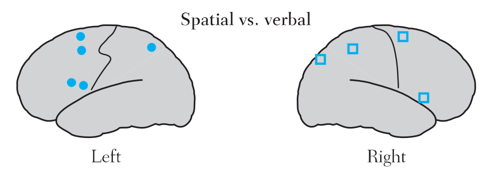
Findings from other brain-damaged people have implicated areas in the frontal lobe as having much to do with WM, perhaps because frontal-lobe damage is often reported to disrupt attention, planning, and problem solving (that is, the central executive in Baddeley's model; see Gathercole, 1994). Shimura (1995) suggested that these problems may arise not because attention and planning are located in the frontal lobe but rather because areas of the frontal

lobe inhibit activity in the posterior part of the brain. People with frontal-lobe damage seem more distractible and less able to ignore irrelevant stimuli.

PET scan studies also give us more information about the neural underpinnings of memory. Recall that for PET studies, patients are injected with a radioactive compound, then asked to lie still with their head in a doughnut-shaped scanner (Posner & Raichle, 1994). This scanner measures blood flow in different brain regions. The idea is that when a particular area of the brain is being used in a cognitive activity, more blood flows to that area. Smith and Jonides (1997) reported that PET study results confirm many aspects of Baddeley's model of working memory—in particular, different patterns of activation for verbal WM (localized primarily in the left frontal and left parietal lobes; see Figure 5-10) versus spatial WM (localized primarily in the right parietal, temporal, and frontal lobes; see Figure 5-11). Nyberg and Cabeza (2000) reviewed brain-imaging studies of memory conducted in many different laboratories and reported similar findings.

FIGURE 5-11 ■ *Schematic representation of PET activations in left and right hemispheres for the one-dimensional tasks, with control activations subtracted. The filled circles designate activations in the verbal task, and the squares indicate activations in the spatial task. Some activated areas are not shown in the schematics because they were in a midline structure (the anterior angulate, which was activated in both the verbal and object tasks) or in subcortical regions (the left-hemisphere thalamus and right-hemisphere cerebellum, activated in the verbal task) or beneath the lateral surface of the cortex (left-hemisphere insular cortex, activated in the verbal task).*

SOURCE: Smith and Jonides (1997, p. 11).



Other researchers have conducted fMRI studies on what brain regions are activated when information is remembered. Wagner et al. (1998), for example, reported that verbal material that was encoded and remembered produced more activation in certain regions of the frontal and temporal lobes. A similar fMRI study of people learning to remember photographs also indicated greater activity in parts of the left prefrontal and medial temporal lobes (Brewer, Zhao, Desmond, Glover, & Gabrieli, 1998).

How does the activity of different brain regions change as memories are formed? We are far from reaching a complete answer to this question. However, some preliminary answers are emerging. Neil Carlson (1994) described some basic physiological mechanisms for learning new information. One basic mechanism is the *Hebb rule,* named after the man who posited it, Canadian psychologist Donald Hebb. The Hebb rule states that if a synapse between two neurons is repeatedly activated *at about the same time* the postsynaptic neuron fires, the structure or chemistry of the synapse changes. A more general, and more complex, mechanism is called **long-term potentiation.** In this process, neural circuits in the hippocampus that are subjected to repeated and intense electrical stimulation develop hippocampal cells that become more sensitive to stimuli. This effect of enhanced response can last for weeks or even longer, suggesting to many that this could be a mechanism for long-term learning and retention (Baddeley, 1993b). As you might suspect, disrupting the process of long-term potentiation (say, through different drugs) also disrupts learning and remembering.

Despite the intriguing results from neuropsychological studies, we are far from having a complete picture of how the brain instantiates all, or even many, memory phenomena. It is not clear which aspects of memory are localized in one place in the brain and which are distributed across different cortical regions. It is not clear what kinds of basic neural processes are involved in any one particular complex cognitive activity. Tulving (1995) made the point quite explicitly:

> Memory is a biological abstraction. There is no place in the brain that one could point at and say, Here is memory. There is no single activity, or class of activities, of the organism that could be identified with the concept that the term denotes. There is no known molecular change that corresponds to memory, no behavioral response of a living organism that is memory. Yet the term *memory* encompasses all these changes and activities. (p. 751)

Tulving noted further that neuroscientists today reject the idea of studying memory as though it were a single process. Instead, they are likely to look for neurological underpinnings at a more precise level—at such processes as encoding or retrieval.

Summary

1. Memory is a very basic cognitive process used in almost every cognitive activity. It involves encoding information, storing it, and later retrieving it from that storage. Cognitive psychologists consider memory an active, constructive process. This means the information does not "sit still" in a storehouse, waiting to be retrieved, but instead is elaborated and sometimes distorted or constructed.
2. One approach to the study of memory, called the *modal approach,* divides memory into different types: *sensory memory,* which holds information in specific modalities for fractions of a second up to several seconds (depending on the modality); *STM,* which holds a limited amount of information for brief periods of seconds or minutes; and *LTM,* which holds onto memories for longer periods of time.

3. The number of unrelated pieces of information that can be held in the short term (without rehearsal or recoding) seems to be seven, plus or minus two. This limit can be overcome through techniques such as *chunking,* which requires some knowledge about the pieces of information and how they relate.
4. There is controversy in the explanations proposed for why we forget information. The question is whether information in a memory store ever decays or "disintegrates" or whether all supposedly "forgotten" information is actually buried information displaced by interference from other information. Although these two possibilities are quite distinct, as a practical matter it is very difficult to design critical experiments that would rule out one of them. Perhaps both kinds of processes play some role in forgetting.
5. Saul Sternberg's work suggests that retrieval from STM is serial and exhaustive. Later work suggests that this may depend on the nature of the stimuli presented.
6. A newer conception of STM, proposed by Alan Baddeley, is called *working memory (WM).* Working memory is thought to consist of a *central executive,* concerned with coordinating and controlling incoming information; a *phonological loop,* acting as an inner "ear"; and a *visuospatial sketch pad,* used as an inner "eye." Recent work suggests that WM capacity is a powerful variable, relating to the ability to resist distraction and distortion, to reason with abstract or concrete premises, and to maintain control of attention more generally.
7. Neuropsychological studies of memory provide a glimpse at some very exciting "cutting-edge" research. Investigators are examining the role of particular brain structures, such as the hippocampus and medial temporal cortex, in memory formation, as well as attempting to localize the brain regions involved in encoding and retrieval.

Review Questions

1. Review the evidence that has led some psychologists to posit the existence of different memory stores (such as sensory memory, short-term memory, long-term memory).
2. Discuss the importance of research on icons and echoes for understanding how people process incoming information. Consider issues of both experimental control and ecological validity.
3. Psychologists have posited two distinct mechanisms for forgetting: decay and interference. Describe each, briefly review the experimental evidence supporting each, and state the problem in distinguishing between them.

4. Describe the methods used in S. Sternberg's memory-scanning experiment. What do the results tell us about retrieval of information from STM?
5. How does Baddeley's conception of working memory differ from traditional descriptions of STM?
6. Explain why WM capacity, but not STM capacity, would relate to performance on so many other cognitive tasks (such as proactive interference, dichotic listening, and reasoning).
7. Describe two ways in which our knowledge of findings from research on working memory can help us design effective real-world strategies for coping with everyday tasks and problems.
8. Summarize the findings of neuropsychological research on localizing memory in the brain.

Key Terms

anterograde amnesia
capacity
central executive (of WM)
chunking
coding
decay
echo
encoding
exhaustive search
forgetting
icon
interference
long-term memory (LTM)
long-term potentiation
memory trace
modal model of memory
parallel search
phonological loop (of WM)
primacy effect
proactive interference
recency effect
rehearsal
retention duration
retrieval
retrograde amnesia
self-terminating search
sensory memory
serial position effect
serial search
short-term memory (STM)
storage
visuospatial sketch pad (of WM)
working memory (WM)

CogLab Demonstrations

To check your knowledge of the key concepts in this chapter, take the chapter quiz at http://www.thomsonedu.com/psychology/galotti. Also explore the hot links that provide more information.

CogLab, a web-based set of demonstrations in cognitive psychology, provides several demonstrations of memorial phenomena discussed in this chapter. Here are four I particularly want to call to your attention: The **Partial Report** demonstration will provide you with experience with Sperling's icon. The **Brown–Peterson** demonstration presents an adapted version of the recall of a trigram task. The **Sternberg Search** demonstration allows you to participate in a short-term memory search experiment, and the **Serial Position** demonstration gives you experience with serial position curves.

Web Resources

Visit our website. Go to http://www.thomsonedu.com/psychology/galotti, where you will find online resources directly linked to your book, including quizzes, flashcards, crossword puzzles, and glossaries.

CHAPTER

6

Retrieving Memories From Long-Term Storage

In the last chapter, we focused on the formation of new memories and on memories held for brief periods of time—fractions of a second, a few seconds, or a minute. In this chapter, we will focus on memories held for longer periods—several minutes, hours, weeks, years, and even decades. The kind of memory we'll be talking about corresponds better than STM does to the layperson's definition of a memory: information retrieved after some long period of storage.

We will begin by looking at the traditional view of long-term memory, the modal model of memory. Recall that this model of memory emphasizes the different memory stores: sensory, short term, and long term. Next we'll turn our attention to other models of memory that focus less on the type of memory store and more on the way information is processed, both at the time of encoding and at the time of retrieval. We'll look at how various cues become associated, either intentionally or unintentionally, with the information to be

remembered, and then at how these cues can be used to maximize the chances of retrieving information.

Our third major topic will be a look at the malleability of memory. In this section, we'll review research on memory for events, and how those memories can be distorted without a person's awareness. Finally, we will look in greater detail at the topic of amnesia, reviewing the different types of amnesia. We'll examine what the clinical data so far tell us about the laboratory-based theories of memory organization.

■ THE TRADITIONAL VIEW OF LONG-TERM MEMORY

In the modal model, long-term memory (LTM) is thought to differ from short-term memory (STM) in many ways. LTM is described as a place for storing large amounts of information for indefinite periods of time. Note the contrast here with the modal description of STM as holding a very limited amount of information (seven, plus or minus two, pieces of unrelated information) for a very short period of time (seconds or at most a few minutes). In other words, LTM is commonly thought to be a sort of mental "treasure chest" or "scrapbook": The material you have cognitively collected in your lifetime is stored there in some form. In this section, we will examine the capacity, coding, storage, and retrieval of information from long-term storage, as well as review evidence bearing on forgotten material.

Capacity

What is the capacity of LTM? The question cannot be answered with a single number. Think about information you have stored in your LTM. It would have to include your memory of all the word meanings you know (probably between 50,000 and 100,000), all the arithmetic facts, and all the historical, geographic, political, and other kinds of information you've learned. You also probably stored in LTM at one time or another the names and faces of all sorts of people: family members, significant teachers, neighbors, friends, enemies, and others. You also surely have stored various pieces of other information about each of them: physical attributes, birthdays, favorite color or musical group, and so on. All your information about various ways of doing familiar things—getting a transcript from the registrar's office; checking out a book from the library; asking for, accepting, or turning down a date; finding a phone number; addressing a letter—must also be in LTM. Indeed, a complete list of all information you have stored at one time or another put into long-term storage would be very long. This intuition has led psychologists to estimate that the capacity of LTM is virtually unlimited.

Thomas Landauer (1986) has tried to provide a more quantitative answer to this question. He begins with two previous estimates. The first is that the size of human memory is equal to the number of synapses in the cerebral cortex of the brain. As you may remember from your introductory psychology course, a synapse is the gap between two neurons, basic cells of the body, across which neurotransmitters pass chemical messages. The cerebral cortex has 10^{13} synapses, so some believe that human memory can hold 10^{13} distinct bits of information.

Another estimate is 10^{20} bits of information, the estimated number of neural impulses, or electrical messages, transmitted within the brain during a person's lifetime. Landauer argued that both these estimates are probably too high: Not every neural impulse or synaptic connection results in a memory. Through various different analyses, in which he tried to estimate the rate at which new information is learned and the rate at which information is forgotten or lost, he came to an estimate of about 1 billion bits of information for an adult at midlife (say, about age 35).

Whatever the actual number of bits of information stored in LTM, not all that information is retrievable at any given moment. Indeed, there are many everyday examples of failures to retrieve information. You meet someone you know you know but can't place, or you think of a word but can't name it. The information probably is in your long-term storage somewhere, but you somehow can't access it. We'll return to the issues of retrieval and forgetting later.

Coding

Many studies of recall from LTM report a common finding: Errors made while recalling information from LTM are likely to be semantic confusions. That is, words or phrases that mean things similar to the words or phrases actually presented are likely to be "recalled" in error, if errors are made. Baddeley (1966a) demonstrated this phenomenon experimentally. He presented participants with lists of words that sounded similar (such as *mad, map, man*) or that were matched to the first list but did not sound alike (such as *pen, day, rig*). Others also saw a list of words with similar meanings (such as *huge, big, great;* such words are called "semantically similar") and another list of control words that were matched to the third list but did not share meaning (such as *foul, old, deep*). Recall was tested after a 20-minute interval, during which participants worked on another task, to prevent rehearsal and to ensure the material would be drawn from long-term rather than short-term storage. The results showed that acoustic similarity produced little effect on performance but that the list of semantically similar words was harder to learn. Baddeley (1976), reviewing this and other work, concluded that the following generalization, although not absolute, is roughly true: Acoustic similarity affects STM; semantic similarity affects LTM.

Retention Duration

How long can information be stored in LTM? Although most laboratory experiments test recall after several hours or days, evidence is abundant that at least some information can last for decades or even a lifetime. Harry Bahrick (1983, 1984) has studied people's memory for material learned to varying degrees at varying times, including memory for the faces of college classmates 20 or 30 or even 50 years after graduation.

In one study, Bahrick (1984) tested 733 adults who had taken or were taking a high school or college course in Spanish. The participants who were not currently enrolled in a Spanish course had not studied Spanish for periods ranging from 1 to 50 years. They also varied in their original degree of learning of Spanish. Bahrick plotted "forgetting curves" for different aspects of knowledge of Spanish—for example, grammar recall and idiom recognition. Although forgetting differed slightly as a function of the measure, the pattern of results was remarkably consistent. For the first 3 to 6 years after completing Spanish study, participants' recall declined. But for the next three decades or so, the forgetting curve was flat, suggesting no further loss of information. Retention showed a final decline after about 30 to 35 years.

Bahrick (1984) interpreted the findings as follows:

> Large portions of the originally acquired information remain accessible for over 50 years in spite of the fact the information is not used or rehearsed. This portion of the information in a "permastore state" is a function of the level of original training, the grades received in Spanish courses, and the method of testing (recall vs. recognition), but it appears to be unaffected by ordinary conditions of interference. (p. 1)

So you thought that after the final exam you'd forget everything about cognitive psychology? If your professor contacts you in 20 years or so, you might surprise both of you: You'll probably remember at least some of the course material!

Another study of Bahrick's (1983) examined people's recall of the spatial layout of a city over a period of time ranging from 1 to 50 years. Bahrick's research participants were 851 current students and alumni of Ohio Wesleyan University, where he was on the faculty. Bahrick asked his participants to describe the campus and the surrounding city of Delaware, Ohio. Specifically, he asked participants:

1. To list all the street names in Delaware that they could recall and to categorize each as running north–south or east–west
2. To recall names of buildings and landmarks in the city and on the campus
3. Using a map provided, to write down the names of all the streets, buildings, and landmarks indicated on the map

4. Given a list of streets or buildings and landmarks, to cross out ones they did not recognize and to categorize each street as running north–south or east–west or to order the landmarks/buildings recognized on the two compass directions
5. Given the map and the lists, to match the street names to the streets and the buildings/landmarks to the indicated squares

Bahrick also asked participants how long they had lived in Delaware (excluding alumni who had lived in the town for more than two years before or after their undergraduate years), the frequency of their visits back to Delaware (for the alumni), and the frequency with which they had driven a car around Delaware and/or used maps. Bahrick used these data to adjust for the fact that some participants had more and/or different kinds of experience with the city than others.

Using the data from the current students, Bahrick (1983) plotted information acquisition as a function of time spent in Delaware. His results show learning of street names occurred at a steady rate over 36 months of residence. In contrast, the learning of building and landmark names showed a steeper curve, with most learning occurring during the first year. Bahrick speculated that the difference in learning rates stems from the facts that campus locations are much more important to learn for students than are the names of streets and that students spend much more time walking around a small area of the city and campus than they spend driving around the city streets.

Bahrick (1983) assessed retention of information by surveying alumni who had graduated from 1 to 46 years previously. These findings were in some ways the inverse of the learning data. Street names (which had been learned slowly and steadily) were forgotten quickly (see Figure 6-1): Most information about street names was lost after 10 years. Names of landmarks and buildings (see Figure 6-2) faded more slowly; 46 years after graduation, alumni retained about 40% of the information that current graduating seniors had (the test included only landmarks and buildings that had existed for 50 years).

Forgetting

If information can last indefinitely in LTM, why does so much of it seem unavailable, even a week later? There are several familiar examples: "knowing" you know the answer to an exam question but being unable to quite remember it; meeting someone on the street who is extremely familiar but you don't know from where. What has happened to your memory in these instances? Has it been erased somehow?

FIGURE 6-1 ■ *Adjusted retention curves of street names.*
SOURCE: Bahrick (1983, p. 138).

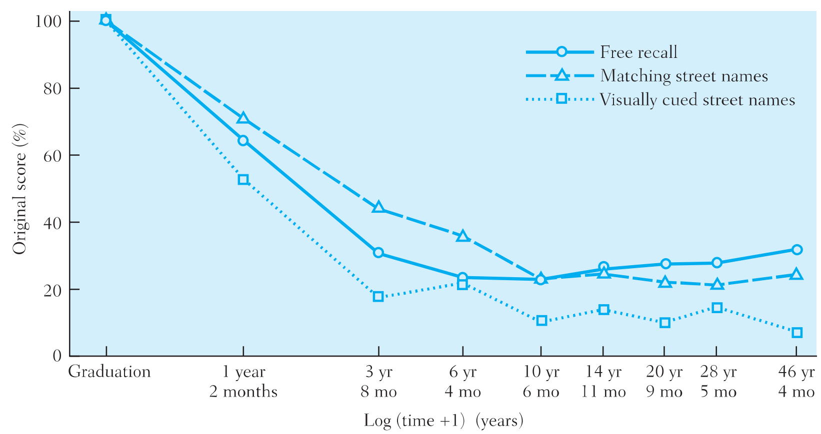
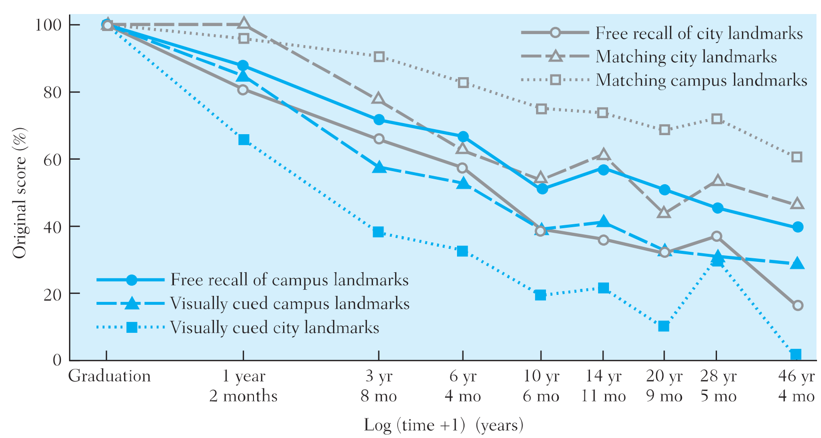


FIGURE 6-2 ■ *Adjusted retention curves of landmarks.*
SOURCE: Bahrick (1983, p. 153).



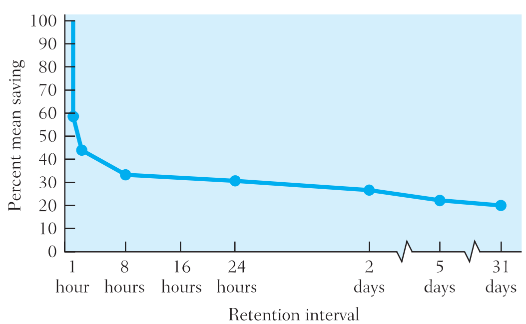
Forgetting or even "misremembering" is a topic that dates back to the early days of experimental psychology. Hermann Ebbinghaus, a Prussian psychologist, pioneered the empirical study of memory under controlled conditions (Hoffman, Bamberg, Bringmann, & Klein, 1987). His master work (Ebbinghaus, 1885/1913) reported on 19 of his studies using himself as a subject.

Ebbinghaus created stimuli he thought were carefully controlled and free from any contamination from prior learning; he called them *nonsense syllables* (such as *rur, hal,* and *beis*). He carefully and precisely presented, at a controlled rate, hundreds of lists of these syllables to a single and dedicated subject: himself. Day after day, Ebbinghaus memorized, tested himself, recorded the results, and prepared new stimuli. Altogether, he spent about 830 hours memorizing 85,000 syllables in 6,600 lists (Hoffman et al., 1987). The primary questions he asked had to do with the number of repetitions needed for perfect recall, the nature of forgetting, the effects of fatigue on learning, and the effects of widely spaced versus closely spaced practice.

One of Ebbinghaus's many findings is presented in Figure 6-3. Depicting a "forgetting curve," the graph plots the amount of time it took him to relearn a list of nonsense syllables after initial learning followed by a retention interval of varying amounts of time (the retention interval is plotted on the *x* axis). Ebbinghaus assumed that the more forgetting, the more effort it would take to relearn a list; conversely, the less forgetting, the less effort to relearn. The curve suggests that forgetting is not a simple linear function of time. Instead, forgetting is rapid at first and then levels off. Notice how well this laboratory finding anticipates the real-world memory studies of Bahrick, reported earlier.

FIGURE 6-3 ■ *Ebbinghaus's (1885/1913) forgetting curve.*

SOURCE: Ebbinghaus (1885/1913, p. 76).



As with STM, many psychologists believe that interference, not decay, accounts for "forgetting" from LTM (McGeoch, 1932). They believe material that can't be retrieved successfully from LTM is there but "buried" or in some other way unavailable. (You may want to review Chapter 5 for a discussion of decay versus interference accounts of forgetting.)

Much of the literature on interference has used a task called **paired associates learning.** Participants hear lists of pairs of words such as *flag–spoon* and *drawer–switch*. After one or more presentations of a list, the experimenter then presents participants with the first word in each pair—for example, *flag*—and the participant is asked to recall the word originally paired with it, such as *spoon*.

Researchers have used this task to study interference in two ways (see Table 6-1). The first is through *proactive interference (PI),* a phenomenon described in Chapter 5. The term *PI* refers to the fact that previous learning can make retention of subsequent learning more difficult. Thus if a group of participants learns a list of paired associates ("List A–B" in the table) and then learns a second list with the same set of first terms but new second ones ("List A–C" in the table), recalling information from the second list is harder.

Table 6-1 Experimental Paradigms for Assessing Proactive and Retroactive Interference

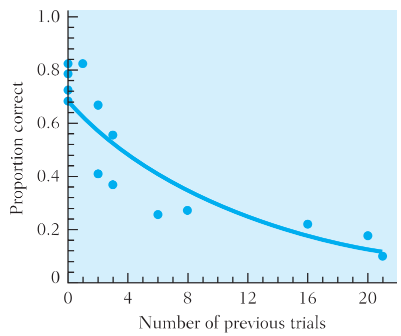
Phase	*Experimental Group*	*Control Group*
Proactive Interference		
I	Learn List A–B	(Unrelated activity)
II	Learn List A–C	Learn List A–C
Test	List A–C	List A–C
Retroactive Interference		
I	Learn List A–B	Learn List A–B
II	Learn List A–C	(Unrelated activity)
Test	List A–B	List A–B

A more familiar example of proactive interference might come from foreign language vocabulary learning. Imagine you are taking beginning courses in French and in German at the same time and for some perverse reason you decide to study their vocabularies sequentially. You first learn a list of French words by pairing them with their English alternatives—for example, *dog–chien*. Next, you learn the German equivalents for the English words, again by pairing—for example, *dog–Hund*. If we compare how well you perform on a test of German vocabulary to the performance of your roommate (who is not studying French), we'll generally find, all other things being equal, that your recall is not as good. We call the kind of interference you experience *proactive* to indicate that earlier material is interfering with subsequent material.

Underwood (1957) demonstrated the effects of proactive interference using the data from 14 studies (see Figure 6-4). These data show that the more previous experience (that is, number of experimental trials) a person has with a particular task, the worse that person's performance is on the current trial.

FIGURE 6-4 ■ *Proportion correct plotted as a function of the number of previous trials. Data were collected from 14 different studies.*

SOURCE: Neath (1998, p. 141), adapted from Underwood (1957).



The other kind of interference is called **retroactive interference.** Imagine you and another friend both study a list of English words and their French equivalents. Your friend now works on a physics problem set while you work on a list of the same English words with their German equivalents. The next day, you and your friend take a quiz in French class. All other things being equal, your recall of French will be worse than your friend's, because of retroactive (or backward) interference. Presumably, your recall of French is contaminated by intrusions of your recall of German.

Some researchers have argued that interference plays a role in most, if not all, forgetting of material from the long-term storage system (Barnes & Underwood, 1959; Briggs, 1954; Postman & Stark, 1969). Of course, it is impossible to rule out the idea that decay occurs, because it is impossible to design a task in which interference cannot occur.

How exactly does interference work? Anderson and Neely (1996) presented several possibilities. They started with the assumption diagrammed in

Figure 6-5(A): that a **retrieval cue** points to, and leads to the recovery of, a target memory. However, when that retrieval cue becomes associated to other targets, during retrieval the second target "competes" with the first. Anderson and Neely offered the following example:

> Consider, for example, the deceptively simple task of recalling where you parked your car at a local shopping center. If you have never before been to that shopping center, recalling your car's location may be fairly easy. If you park there frequently, however, you may find yourself reunited with the spot where you parked yesterday or, if you are like the present authors, standing befuddled at the lot's edge. Further, if asked where you parked on previous visits, you would almost certainly fail to recall the locations, as though your intervening parking experiences had overwritten those aspects of your past. (p. 237)

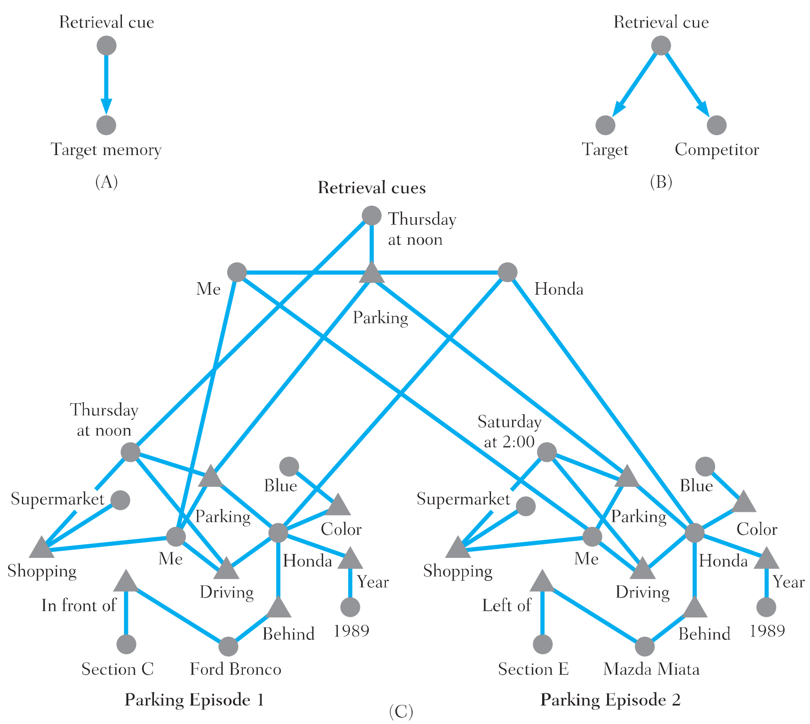
Put in terms of Figure 6-5(B), the more times you park in a particular parking lot, the more "targets" (actual parking spots) get associated with a retrieval cue (such as the question you ask yourself as you leave the store, "Now where did I park?"). The more possible targets associated with the cue, the less the chances of finding any particular one of them. Complicating matters even further, a given retrieval cue can become associated with different targets (or other cues), leading to even more complexity, as diagrammed in Figure 6-5(C), and making it that much harder to traverse a path from the cue to the correct target.

To account for some of these results, psychologist John Anderson (1974; Anderson & Reder, 1999) described a phenomenon known as the **fan effect.** Anderson's idea is that as research participants study more facts about a particular concept, the time they need to retrieve a particular fact about that concept increases. So, for example, if you study lots of facts about forgetting, your ability to recall any individual fact about it (for example, that many psychologists think it is caused by interference) is slowed.

Anderson and Neely (1996) speculated that forgetting may not be so much a shortcoming of memory as a side effect of our ability to direct memory. In particular, they wonder whether sometimes it is beneficial to be able to forget voluntarily. Example: You are working for the summer break as a short-order cook. Servers spend their time shouting orders at you: "Egg salad on wheat, lettuce, no mayo!" It behooves you both to maintain this information in immediate memory as you construct the sandwich *and* to clear this information when you are done so it does not interfere with newer incoming orders. Laboratory work that Anderson and Neely reviewed suggests that when people lose information through "directed" (voluntary or intentional) forgetting, they experience much less proactive interference. Forgetting, then, can be a useful thing to do!

FIGURE 6-5 ■ *Illustration of the notion of competition among items sharing the same retrieval cue. (A) A retrieval cue that is associated to only one target item in memory. (B) The basic situation of interference, in which a retrieval cue becomes associated to one or more additional competitors that impede recall of the target, given presentation of the shared retrieval cue. (C) How the basic situation of interference illustrated in (B) may be applied to understand a more complex example of interference in which two episodes of having parked at the supermarket interfere because they share the retrieval cues "Me," "Honda," and "Parking" at the time of retrieval. Circles and triangles in the representations of Episodes 1 and 2 in (C) depict concepts and relations, respectively.*

SOURCE: Anderson and Neely (1996, p. 240).



In this section, we've explored mechanisms for forgetting or at least being unable to retrieve previously stored information. It makes sense now to ask, What happens to information that is retained instead of forgotten? Let's look now at how information from LTM is retrieved successfully.

Retrieval of Information

Suppose you want to improve your chances of recalling information at a later date (for example, to study for an upcoming midterm in cognitive psychology). What do we know about retrieval that can help? In Chapter 9 we'll discuss a number of **mnemonics,** techniques to improve memory, many of them having to do with visual imagery. For the present, we will consider a few principles of retrieval that can be used to aid recall.

The first is the principle of categorization. This states that material organized into categories or other units is more easily recalled than information with no apparent organization. This effect happens even when organized material is initially presented in a random order.

Bousfield (1953) presented participants with a list of 60 words. The words came from four categories—animals, names, professions, and vegetables—but were presented in scrambled order. Nevertheless, participants tended to recall the words in clusters—for example, a number of animals together, then a group of vegetables, and so on. It turns out that even if the material doesn't have apparent organization, asking people to organize it into their own subjective categories improves recall (Mandler, 1967).

How can we apply the principle of categorization to your studying for a midterm? Simply put, the best advice is to categorize and organize your information! Make a list of theories of forgetting, for example, and organize your notes about memory phenomena around this list. That way, if you are asked to write an essay about theories of forgetting, you will likely recall more of the relevant information.

A second principle of retrieval, discovered by Thomson and Tulving (1970), is called **encoding specificity.** The idea is that when material is first put into LTM, encoding depends on the context in which the material is learned. The manner in which information is encoded is specific to that context. At the time of recall, it is a great advantage to have the same context information available. Aspects of the context function as cues to the retrieval.

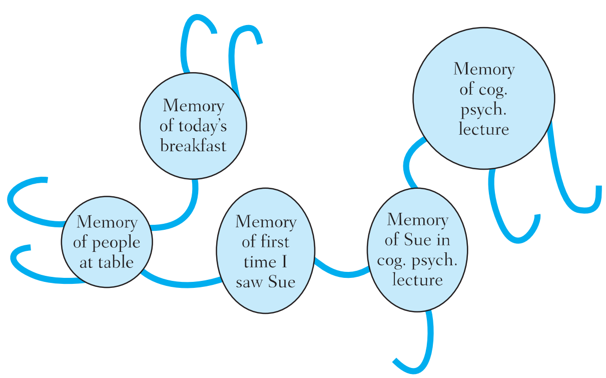
Tulving and Thomson (1973) demonstrated the encoding specificity principle as follows. Participants saw lists of words, with the to-be-remembered words printed in capital letters. Some participants saw these "target" words paired with other words printed in small letters. Both groups were told that the words in small letters were cues or hints. Cues were either highly related to the target (such as *hot–COLD*) or not very related (such as *ground–COLD*).

Participants in the control condition were presented with the target words, but no cues (such as *COLD*).

At recall, participants in the control condition (who hadn't seen any cues during the learning phase of the task) were aided if highly related cues were presented, even though these cues hadn't been seen in the learning phase. In contrast, as you might expect, the not-very-related cues were not very effective in prompting recall. However, the results were very different for participants who *had* seen cues during the learning phase. For these participants, the not-very-related cues were in fact effective in aiding recall, even better than highly related cues that had not been presented during the learning phase. Thomson and Tulving believed that even a weakly related word can become a retrieval cue if it is presented at the time of encoding.

To help your understanding of encoding specificity, you might think of material stored in LTM as a series of bubbles with hooks attached, as shown in Figure 6-6. The bubbles contain the material to be stored. The hooks represent information associated with the material. Apparently, many of these associations are formed at the time the to-be-remembered material is first encoded. If these hooks are created at encoding and are presented again at the time of attempted retrieval, the target material in the bubble is retrieved easily, by a process akin to mentally grabbing one of the hooks.

FIGURE 6-6 ■ *Abstract depiction of long-term memory storage. Circles represent units of information. "Hooks" that are attached to the information at the initial encoding depict associations to the information and attach one unit of information to another.*



Roediger and Guynn (1996) summarized the encoding specificity hypothesis slightly differently:

> A retrieval cue will be effective if and only if it reinstates the original encoding of the to-be-remembered event. When a word like *black* is presented without context, it is presumably encoded with regard to its dominant meaning (as associated with *white*). Therefore, *white* serves as an effective retrieval cue, and a weak associate like *train* does not. However, when *black* is encoded in the context of a weak associate like *train*, subjects are likely to engage in a more idiosyncratic encoding of the target word (e.g., they might imagine a black train). In this case, the weak associate could serve as an excellent retrieval cue, but now the strong associate is completely ineffective. (p. 208)

Apparently, even information unrelated to the material, such as the environmental stimuli present at the time of encoding, can become a hook. One of my favorite studies is that by Godden and Baddeley (1975), who presented lists of 40 unrelated words to 16 scuba divers, all wearing scuba gear. Divers learned some of the lists on the shore and the others 20 feet under water. They were later asked to recall the words either in the same environment where they were learned or in the other environment. Results showed that recall was best when the environment was the same as the learning environment. Lists learned underwater were best recalled underwater, and lists learned on the shore were recalled best on the shore. This finding, that recall is best when performed in the original environment, is called a **context effect.**

Interestingly, researchers later found that recognition memory does not show the same context effect (Godden & Baddeley, 1980), suggesting that recognition and recall work differently. In particular, this finding suggests that physical context affects recall but not recognition (Roediger & Guynn, 1996). Presumably, in the former task the participant must do more work to generate his or her own retrieval cues, which may include certain features of the learning environment, whereas in the latter task, the test itself supplies some retrieval cues (in the form of the question and the possible answers).

Other studies have demonstrated similar effects (called **state-dependent learning**) with pharmacological states: Material learned while someone is chemically intoxicated (for example, by alcohol or marijuana) is usually recalled better when the person recreates that state (J. E. Eich, 1980). By the way, to ensure that you don't use this scientific finding as an excuse to party, I must note that overall performance was best for those participants who learned and recalled material while sober! However, the finding of interest was that participants who learned material while in a chemically altered state showed significantly better recall if they were again chemically intoxicated at the time of recall. Later studies suggest that this **state-dependent memory** effect, like context effect, is found only with recall and not with recognition tasks (Roediger & Guynn, 1996).

Bower (1981) even claimed that a person would recall more information if he or she were in the same mood at recall time as at encoding time. That is, Bower claimed that if you learned information while happy, you would recall that information better if you were in a happy mood again. Over the years, however, this **mood-dependent memory effect** has proven more complicated than this, although recent work suggests the phenomenon does occur under certain conditions (E. Eich, 1995).

Further support for the encoding specificity hypothesis comes from a phenomenon known as the **spacing effect** (Ross & Landauer, 1978). You may already be familiar with this effect because it restates advice that teachers often give. Simply, if you repeatedly study the same material, you are much better off with a number of short study sessions spaced some time apart than you are with one long session. (In other words, don't cram!) Ross and Landauer noted, "In most cases, two immediately successive presentations [of a piece of information] are hardly more effective than a single presentation, while two well spaced presentations are about twice as effective as one" (p. 669).

A variety of theories seek to explain the spacing effect (Glenberg, 1977; Ross & Landauer, 1978). One of the most common is called **encoding variability.** In terms of the model in Figure 6-6, spacing allows the context of encoding to change, so a wider variety of hooks can be attached to the material. The greater the number of hooks, the greater the chances of getting hold of one or more of them at the time of retrieval. Thus the spacing effect is explained primarily in terms of the encoding specificity principle.

Another concept relevant to retrieval from long-term memory is **cue overload** (Roediger & Guynn, 1996). The basic principle here is that a retrieval cue is most effective when it is highly distinctive and not related to any other target memories. For example, we all remember dramatic, unusual events better than we do routine, more mundane events.

Marigold Linton (1982) conducted a study that nicely demonstrates this principle. Like Hermann Ebbinghaus, she studied her own memory. Like those of Ebbinghaus, her methods of data collection have a heroic quality: Every day for six years (!), she wrote brief descriptions of two (or more) events that had happened that day. Each month, she conducted tests of her memory.

> Memory tests proceeded as follows: Once a month items were drawn semi-randomly from the accumulated event pool. After reading a pair of randomly paired event descriptions, I estimated their chronological order and attempted to reconstruct each item's date. Next, I briefly classified my memory search (for example, I might "count backwards" through a series of similar events, as school quarters, Psychonomic Society meetings, and the like) and reevaluated each item's salience. After six years the experiment had reached imposing dimensions. I had written more than 5,500 items (a minimum of two times each day) and tested (or retested) 11,000 items (about 150 items each month). Item generation required only a few minutes each day but the monthly test was extremely laborious, lasting 6–12 hours. (pp. 78–79)

Linton (1982) found that some items were easily retrievable: Any description such as "I did *X* for the first time" (for example, went to New York, met a famous psychologist) was very memorable. Other items became harder and harder to recall, especially when the written description did not pertain to a single, distinctive event.

> In 1972 I wrote an item approximately as follows: "I xerox the final draft of the statistics book and mail it to Brooks/Cole." Some years after the third "final draft" had been submitted this item was singularly nondiscriminating. Which event did I mean? Was the item written when I naively believed that the first draft would be the "final draft"? After the second submission when it was clear that the final draft now had been submitted? Or was this allusion to the third submission, which historically became the "final draft"? (pp. 82–83)

Put once again in terms of Figure 6-6, we can offer the following analogy for cue overload. Imagine a hook attached, not to one, but to several circles. Grabbing hold of that hook may lead you to an incorrect target. The more circles a given hook is attached to, the lower the probability it will link you to the correct memory.

THE LEVELS-OF-PROCESSING VIEW

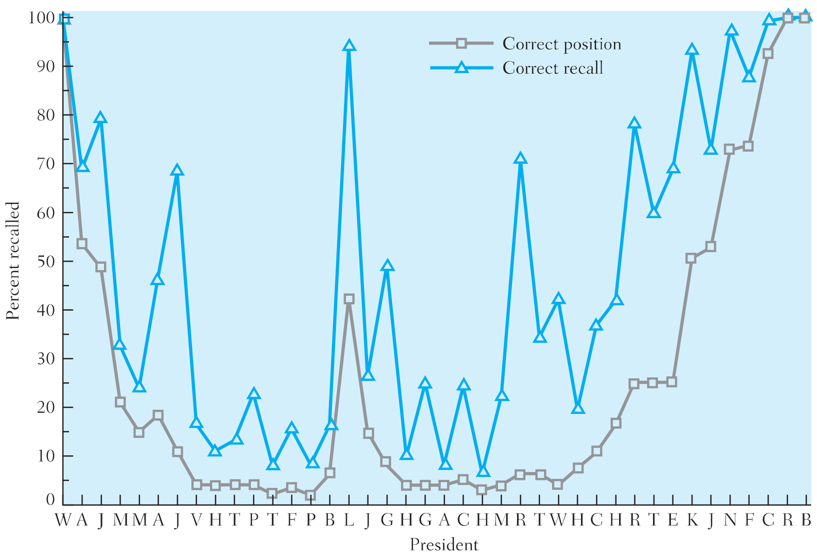
The modal approach to memory makes a distinction between different kinds of memory—for example, sensory memory, STM, and LTM stores. (Review Chapter 5 for a detailed discussion of sensory memory and STM.) Researchers think these components process information differently, store information differently, and retain information for different lengths of time. The component used at any given time depends primarily on how long information is stored.

The modal approach is not universally endorsed, however. Some psychologists argue that there is only one kind of memory storage (Melton, 1963) but that different kinds of information processing take place within that store. Others take issue with the way the modal approach describes certain kinds of memory stores, such as STM.

Crowder (1993), for example, pointed out many different experimental findings that he said were inconsistent with the modal model of STM. To cite just one: If you ask undergraduates to list the names of all the U.S. presidents they can recall, you are likely to obtain a curve such as shown in Figure 6-7. Note that its overall shape looks quite similar to a typical serial position curve; it shows both a primacy and a recency effect. But it is completely implausible to suggest that the existence of the recency effect indicates the undergraduates were drawing on STM to recall the most recent presidents. Although you might want to argue that the size of the recency effect is larger than is typically found (Healy & McNamara, 1996) or that the classic conception of STM can be extended and elaborated to account for such findings (Shiffrin, 1993), the fact remains that the modal model is no longer the only viable explanation of how memory works.

FIGURE 6-7 ■ *Recall of the names of U.S. presidents as a function of their ordinal position.*

SOURCE: Crowder (1993, p. 143).



One alternative to the modal view of memory is the **levels-of-processing theory of memory.** In this model, memory is thought to depend not on how long material is stored or on the kind of storage in which the material is held, but on the initial encoding of the information to be remembered (Craik & Lockhart, 1972). That is, the levels-of-processing approach does not posit

different memory stores (such as STM and LTM) but rather posits different kinds of cognitive processing that people perform when they encode information.

The fundamental assumption is that retention and coding of information depend on the kind of perceptual analysis done on the material at encoding. Some kinds of processing, done at a superficial or "shallow" level, do not lead to very good retention. Other kinds of "deeper" (more meaningful or semantic) processing improve retention. According to the levels-of-processing view, improvement in memory comes not from rehearsal and repetition but from greater depth of analysis of the material.

Craik and Tulving (1975) performed a typical levels-of-processing investigation. Participants were presented with a series of questions about particular words. Each word was preceded by a question, and participants were asked to respond to the questions as quickly as possible; no mention was made of memory or learning. Any learning that is not in accord with the participant's purpose is called **incidental learning.**

In one experiment, three kinds of questions were used. One kind asked the participant whether the word was printed in capital letters. Another asked if the target word rhymed with another word. The third kind asked if the word fit into a particular sentence (for example, "The girl placed the _____ on the table"). The three kinds of questions were meant to induce different kinds of processing. To answer the first kind of question, you need look only at the typeface (physical processing). To answer the second, you need to read the word and think about what it sounds like (acoustic processing). To answer the third, you need to retrieve and evaluate the word's meaning (semantic processing). Presumably, the "depth" of the processing needed is greatest for the third kind of question and least for the first kind of question.

As predicted, Craik and Tulving (1975) found that on a surprise memory test later, words processed semantically were remembered best, followed by words processed acoustically. However, the experiment gave rise to an alternative explanation: Participants spent more time answering questions about sentences than they did questions about capital letters. To respond to this explanation, in subsequent experiments the authors showed that even if the physical processing was slowed down (by asking participants, "Does this word follow a consonant-vowel-consonant-vowel-consonant-vowel pattern?"), memory was still best for more deeply processed information.

Craik and Tulving (1975) initially equated depth of processing with degree of semantic processing. But Bower and Karlin (1974), studying memory for faces, found similar results with nonverbal stimuli: Participants who rated faces for "honesty" showed better memory than participants who rated the faces according to gender. One problem with this approach, though, was pinning down the definition of what defined a level and what made for "depth" (Baddeley, 1978).

Craik and Tulving (1975) found, for instance, that the "meaningfulness" of the initial task was not the only factor that could account for better retention. Participants who were asked to determine if words fit into sentences showed poorer recall for simple sentences (for example, "She cooked the _____") than they did for more complex sentences (for example, "The great bird swooped down and carried off the struggling _____"). Levels-of-processing theory as initially formulated would argue that both words were processed semantically, so that could not account for the difference in recall. Craik and Tulving therefore extended the levels-of-processing idea, arguing that the elaboration of material could also aid recall. Presumably, the second, more complicated sentence calls to mind a richer idea: The sentence itself has more underlying propositions (there was a bird, the bird was very large, the bird swooped down, the bird carried something off) than the first sentence (there is a female, she is baking something). Sentences that specified more precisely the relation of the target word to the context were found especially likely to increase the probability of recalling the target word (Stein & Bransford, 1979).

Craik and Lockhart (1972) viewed memory as a continuum of processes, from the "transient products of sensory analyses to the highly durable products of semantic . . . operations" (p. 676). This view ties memory in with other cognitive systems quite neatly. For example, recall the work on dichotic listening tasks, reviewed in Chapter 4. Recall that material from the unattended channel is typically not remembered after the task is completed. The levels-of-processing approach can account for this finding, holding that material not analyzed for meaning receives only "shallow" processing, which results in poor retention.

Baddeley (1978) presented a thorough critique of the levels-of-processing approach. First, he argued that without a more precise and independent definition of "depth of processing," the usefulness of the theory was very limited. Second, he reviewed studies that showed, under certain conditions, greater recall of information processed acoustically than semantically. Finally, he described ways in which the modal view of memory could explain the typical levels-of-processing findings.

Nonetheless, the levels-of-processing approach did help to reorient the thinking of memory researchers, drawing their attention to the importance of the *way* material is encoded. The approach has helped cognitive psychologists think about the ways in which people approach learning tasks. It has reinforced the idea that the more "connections" an item has to other pieces of information (such as retrieval cues), the easier it will be to remember, a point that fits nicely with the idea of encoding specificity discussed earlier.

Other memory research has also encouraged psychologists to pay attention to how encoding changes with the type of material presented. Some aspects of information, for instance, seem to be encoded without much effort, or even

intention. Frequency of occurrence is one such aspect (Hasher & Zacks, 1984). For example, if you are a movie fan, you see lots of movies, and you may even see some more than once. Although you probably have no reason to keep track of how many times you saw a particular movie, you may have a clear sense you've seen one a few more times than you've seen another. Chances are quite good that your sense is correct. If so, Hasher and Zacks would explain your impression as an instance of *automatic encoding:* Certain aspects of experience, such as frequency of occurrence, have a special representation and are kept track of in memory without effort or even intention.

Other work in various laboratories is aimed at explicating other so-called unitary models of memory, which do not assume different processes for short- and long-term memory. Like Craik and Tulving, psychologist James Nairne (2002) argues against positing distinct short- and long-term memory stores. What differs for memories recalled after a few seconds versus after several years, Nairne believes, are the retrieval cues that are in effect. Thus, unlike Craik and Tulving, who emphasized encoding processes, Nairne focuses instead on retrieval.

THE RECONSTRUCTIVE NATURE OF MEMORY

Thus far, we have concentrated on laboratory studies of memory. This tradition dates back at least to Ebbinghaus. One can't help admiring Ebbinghaus's dedication and feeling gratitude for his many insights about memory. However, a similarly common reaction is to find his efforts somewhat amusing. After all, what relevance do his heroic studies have to memory in "real life"? Does the study of memory for nonsense syllables really tell us very much about how to study for an upcoming midterm, how to remember where we left our house key, or how we recall our first day of kindergarten (if in fact we remember anything about it)?

Another pioneer in the study of memory, Frederick Bartlett, rejected the emphasis on laboratory studies of memory. Bartlett (1932) believed that in the real world (as opposed to the laboratory) memory largely uses world knowledge and **schemata—**frameworks for organizing information. According to Bartlett, at retrieval time this knowledge and organizational information is used to reconstruct the material. Bartlett tested both friends and students, first presenting them with stories such as the one in Box 6-1.

Bartlett used the method of serial reproduction, meaning participants were asked to recall the stories on more than one occasion. Participants were asked to recall the tales at varying intervals, some as long as years. Bartlett was interested in what information was remembered and what information

Box 6-1 "The War of the Ghosts": A Story Used by Bartlett (1932) to Investigate Long-Term Memory

One night two young men from Egulac went down to the river to hunt seals, and while they were there it became foggy and calm. Then they heard war-cries, and they thought: "Maybe this is a war-party." They escaped to the shore, and hid behind a log.

Now canoes came up, and they heard the noise of paddles, and saw one canoe coming up to them. There were five men in the canoe, and they said: "What do you think? We wish to take you along. We are going up the river to make war on the people." One of the young men said: "I have no arrows." "Arrows are in the canoe," they said.

"I will not go along. I might be killed. My relatives do not know where I have gone. But you," he said, turning to the other, "may go with them." So one of the young men went, but the other returned home.

And the warriors went on up the river to a town on the other side of Kalama. The people came down to the water, and they began to fight, and many were killed. But presently the young man heard one of the warriors say: "Quick, let us go home: that Indian has been hit." Now he thought: "Oh, they are ghosts." He did not feel sick, but they said he had been shot.

So the canoes went back to Egulac, and the young man went ashore to his house, and made a fire. And he told everybody and said: "Behold I accompanied the ghosts, and we went to fight. Many of our fellows were killed, and many of those who attacked us were killed. They said I was hit, and I did not feel sick." He told it all, and then he became quiet. When the sun rose he fell down. Something black came out of his mouth. His face became contorted. The people jumped up and cried.

He was dead.

SOURCE: Bartlett (1932, p. 67).

was "misremembered"—distorted or reordered in the participants' recollections. Box 6-2 provides examples of repeated recollections of the "War of the Ghosts" story as retold by one participant. This retelling shows concretely that over time, the same person's recall becomes more distorted.

Bartlett used this evidence to argue for a constructive view of long-term memory (LTM). He believed that participants unintentionally introduced the distortions to make the material more rational and more coherent from their own point of view. Interestingly, the original story, a Native American folktale, was often "misrecalled" in ways more consistent with people's cultural conventions for stories. Thus, the "foggy and calm" weather might be changed to a "dark and stormy night"—something more in keeping with a Western assumption of how weather portends bad events. Bartlett thus rejected the idea of LTM as a warehouse where material is stored unchanged until retrieval. Rather, he saw memory as an active and often inaccurate process that encodes and retrieves information so as to "make sense."

Box 6-2 One Participant's Recall of "The War of the Ghosts"

Recalled 15 minutes after hearing story:

The Ghosts

There were two men on the banks of the river near Egulac. They heard the sound of paddles, and a canoe with five men in it appeared, who called to them, saying: "We are going to fight the people. Will you come with us?" One of the two men answered, saying: "Our relations do not know where we are, and we have not got any arrows." They answered: "There are arrows in the canoe." So the man went, and they fought the people, and then he heard them saying: "An Indian is killed, let us return." So he returned to Egulac, and told them he knew they were ghosts.

He spoke to the people of Egulac, and told them that he had fought with the Ghosts, and many men were killed on both sides, and that he was wounded, but felt nothing. He lay down and became calmer, and in the night he was convulsed, and something black came out of his mouth.

The people said: "He is dead."

Recalled two weeks later:

The Ghosts

There were two men on the banks of a river near the village of Etishu (?). They heard the sound of paddles coming from the up-stream, and shortly a canoe appeared. The men in the canoe spoke, saying: "We are going to fight the people: will you come with us?"

One of the young men answered, saying: "Our relations do not know where we are; but my companion may go with you. Besides, we have no arrows."

So the young man went with them, and they fought the people, and many were killed on both sides. And then he heard shouting: "The Indian is wounded; let us return." And he heard the people say: "They are the Ghosts." He did not know he was wounded, and returned to Etishu (?). The people collected round him and bathed his wounds, and he said he had fought with the Ghosts. Then he became quiet. But in the night he was convulsed, and something black came out of his mouth.

And the people cried: "He is dead."

SOURCE: Bartlett (1932, pp. 68–69).

Psychologist Ulric Neisser, a major figure in the study of memory, offered related arguments regarding studying memory in natural settings (1982a). Neisser was skeptical of the assumption that laboratory studies of memory are necessarily relevant to memory in natural settings; rather, he believed that laboratory studies are of limited value in understanding the use of memory in everyday life. Neisser called for the study of how people construct and use memories of their own past experiences, how they remember events of historical significance, how they use memory to plan and carry out everyday errands, and so on. In this section, we will take up some of these questions.

Autobiographical Memory

Marigold Linton's (1975, 1982) work, described earlier, is a good example of a classic study of **autobiographical memory**—that is, memory for events that the rememberer has been part of. Recall that she spent six years in a true Ebbinghausian endeavor: studying her own recall of events from her own life. Each day she would record short descriptions of that day's events, typing them onto a 4-by-6 index card, on the back of which she recorded the actual date, as well as different ratings of the event (for example, how clearly distinguishable she believed the event would be in the future, the emotionality of the event, and the importance to her life goals of the event). At the end of the month (when 60 to 90 cards had accumulated), she would gather and randomly sort them into 14 piles for testing during the following three years. Twelve of the piles were tested in the following 12 months; the remaining sets were used two and three years after the events, respectively.

Each month, after doing a brief free recall of life events as a warm-up task, Linton shuffled all the cards due for testing that month, then exposed two cards at a time while starting a stopwatch. She recorded the cards' code numbers, then tried to order the two exposed events (that is, which happened before the other). Her time to perform this ordering was recorded. Next she restarted the stopwatch, timing how long it took to recall the exact date of the left-hand card. Finally, she did the same for the right-hand card.

During the first 20 months of the study, Linton recorded 2003 events and tested 3006 (1468 of these were retests of previously tested items). She had expected, before running the study, that she would quickly forget many of the items, but in fact that did not happen, perhaps because she needed only to recognize the events (not recall them) and to date them, not answer detailed questions about them. In fact, Linton's results suggested that real-world memories are much more durable than those of most laboratory experiments.

Linton also recorded protocols of herself thinking aloud (a technique discussed in Chapter 11) as she tried to date items. She found that she often used problem-solving strategies to arrive at a date, even when she had no explicit recall of the event. You might be able to re-create this phenomenon by trying to answer the following question: Where were you on June 28, 2005, at 11:20 A.M.? Your first reaction may be to laugh and to claim you can't possibly answer the question. But think about it. No doubt you can find some "markers" that point you toward some sort of answer. For instance, you might note that June is during the summer. You might be able to figure out June 28 must have been a Tuesday, because (say) your mother's birthday is June 25, and you remember that being on a Saturday. You might remember you held a summer job at a local department store and conclude that at 11:20 on June 28, you must have been working, probably stocking shelves. Notice that what you've done is to "zero in" on the date and time by finding and using different "markers." You haven't necessarily remembered what you were doing; instead, you've reconstructed it.

Linton also reported on "unrecalled" items and found them to be of (at least) two types. Some were simply not recalled; that is, the description she originally reported did not serve to bring to mind any recollection of the event when it was tested. However, at least as many "forgotten" items were ones Linton found herself unable to distinguish from other, similar memories.

Robinson and Swanson (1990) offered an explanation of Linton's findings on "unrecalled" items. They suggested that as similar events are repeated, the similar aspects start to form an event schema. That is, as Linton repeatedly experienced an event, such as sending what she believed to be a "final" draft of her book to her publisher, memory traces of the specific instances of the different events fused together and became indistinguishable. Linton herself (1982) talked about a transformation from episodic to semantic memory, a topic we will take up in the next chapter.

Barsalou (1988) reported findings consistent with Robinson and Swanson's (1990) proposal. He and his collaborators stopped people on the campus of Emory University during the fall semester and asked whoever agreed to participate to describe events they were involved with during the preceding summer. Although people were asked to report and describe specific events, only 21% of the recollections collected could be categorized as specific recollections. Instead, people were more likely to give "summarized events," statements that referred to two or more events of a certain kind, such as "I went to the beach every day for a week." These summarized events made up almost a third of the recollections collected. People also reported what Barsalou called an "extended event," a single event lasting longer than a day, such as "I worked at a camp for disadvantaged children." Even when Barsalou and his associates pointedly tried to elicit only specific event recollections, their participants still tended to report extended or summarized events.

Brewer (1988) took a different methodological approach to studying recall for ordinary events. He found eight very cooperative undergraduates to serve in a demanding multiweek experiment. During the data acquisition phase, participants were asked to wear beepers programmed to go off on a random schedule about once every two hours. When the beeper sounded, participants were asked to fill out a card with information about the event that had occurred when the beeper went off. Specifically, participants were asked to report the time and their location, actions, and thoughts and then to complete a number of rating scales (rating such things as how often this kind of event occurred, how pleasant the event was, and how trivial or significant). Fortunately, participants were given the option of recording the word "private" on a card instead of giving a detailed account, if the activity they were engaged in was one they preferred for any reason not to report. Brewer noted that most participants exercised this option at least occasionally, which no doubt led to some systematic undersampling of certain kinds of events, such as dating or parties.

Brewer (1988) argued that this methodology had certain advantages over the one Linton used. Obviously, it involves separating the experimenter from the participant, which methodologically has many advantages. More important, however, Brewer argued that Linton wrote down the most "memorable" events of each day, which would tend to skew the set of items to be remembered. Brewer compares Linton's technique to one in which a laboratory participant in an experiment is given lists of hundreds of words each day and is asked at the end of each day to select one word to use in later testing. To compare these techniques, Brewer also asked his participants to list the most memorable event of each day.

Brewer (1988) later tested his participants' recall of the events they had recorded on cards. Each participant was tested three times: once at the conclusion of the data acquisition period, once about 21.2 months later, and once about 41.2 months after the end of the acquisition period. Items tested were randomly selected from all items the participants had initially described.

Brewer (1988) reported very good overall retention from his participants, who recognized more than 60% of the events. Memory was better for actions than for thoughts, and better for "memorable" events than for events randomly prompted by beepers. Consistent with some of the results Linton reported (1975, 1982), Brewer found that events that occurred in a unique or infrequent location were better remembered than occurrences in frequented locations. Similarly, rare actions were more likely to be recalled than frequent actions. Interestingly, the time period of study encompassed the Thanksgiving break for Brewer's participants. Memories from that minivacation were recalled especially well. The reason for this, Brewer argued, was that these trips were taken during the participants' first trip home from college (all the participants were first-year students). Those trips, he believed, were likely to be quite distinctive, especially in comparison with the routine events of going to class and studying that preceded and followed the vacation. Brewer concluded that the more distinct the mental representation of an event, the more likely it is to be recalled, a conclusion similar to the one Linton reached.

In summary, Brewer (1988) concluded that autobiographical memories, while showing many of the phenomena demonstrated in laboratory studies, also showed important differences. Few overt recall errors were found, suggesting to Brewer that "personal memories are reasonably accurate copies of the individual's original phenomenal experiences" (p. 87).

Flashbulb Memories

Where were you when you learned of the terrorist attack on the World Trade Center on September 11, 2001? Many of us recall information not only about

Nancy J. Ashmore

Autobiographical memories include recollections of events both mundane and important. What do you remember about the time you first met your college roommate?

the tragic disaster itself but also about where we were, whom we were with, and what we were doing at the time we first heard about it. For example, I was standing in line at Goodbye, Blue Monday, my town's local coffee store. I'd just had my hair done, and was thinking about all the things I had to do that day, when a woman in a pink dress behind me tapped me on the arm and asked if I'd heard the news. When I got to my car, I turned on the radio, and hurried into school to use my computer to surf the web. For most of the day I listened to the radio, surfed the web, and talked in horrified tones to coworkers. That evening, I took my 8-year-old son to an on-campus service of remembrance. The day seems etched permanently in my memory.

Brown and Kulick (1977) coined the term **flashbulb memory** to describe this phenomenon. Other examples might be found in your parents' or other relatives' recollections of where they were when they heard about the assassinations of John F. Kennedy or Martin Luther King, Jr. A recent study reports on flashbulb memories among Danish World War II veterans of the invasion and liberation of Denmark (Berntsen & Thomsen, 2005). Given the historical importance and surprising nature of these events, it may be small wonder that most of us old enough to have experienced them remember them. Why, though, do we remember details about our own circumstances when we first heard the news? Some have argued that part of the explanation involves our physiological response when we hear such news: Parts of the brain that are involved in emotional responses activate, and the cognitive effects of this activation result in the storage of a great deal of information only indirectly related to the main information (Brown & Kulik, 1977). Pillemer (1984) found, for example, that his participants who reported a stronger emotional reaction to the news of the assassination attempt on President Reagan had stronger and more detailed flashbulb memories.

AP/Wide World Photos

The 9/11 attacks were events that easily led to the formation of flashbulb memories.

Neisser (1982b) offered a different explanation for the origin of flashbulb memories: People are finding a way to link themselves to history. Flashbulb memories come about because the strong emotions produced by the event prompt people to retell their own stories of where they were when they heard the news. Flashbulb memories, then, result from the retellings of stories. Over time, the memories can become distorted, in much the same way that participants in Bartlett's (1932) study distorted their retellings of the "War of the Ghosts" story: People elaborate and fill in gaps in their stories, making them approximate a standard story format.

Stephen Schmidt (2004) offered results of a study on people's flashbulb memories for 9/11. Undergraduates at his university (Middle Tennessee State) filled out survey instruments asking for their recall of the events of 9/11, beginning the very next day (9/12/2001). Students were also resurveyed two months later. In this way, Schmidt was able to compare recollections across a two-month time span. Almost all of his participants were able to report basic "flashbulb" information: who told them about 9/11, where they were when they first heard the news, what activity they were engaged in when they first heard the news, what they were wearing, what the weather was like. Students showed greater consistency in answering what Schmidt calls "central" questions, such as the first three in the list above, and less for "peripheral" questions, such as what they were wearing. However, contrary to prediction, Schmidt found that those participants who initially reported the strongest emotional reaction to the events of 9/11 showed the most impairment in their memory. Interestingly, Daniel Greenberg (2004) analyzed news reports to show that George W. Bush has demonstrated substantial inaccuracies in his own flashbulb memories of the events of that day. Arguably, as the sitting president during the events of 9/11, his reaction was powerfully emotional.

The question of whether flashbulb memories differ in kind from other types of memories has been actively debated (see, for example, Cohen, McCloskey, & Wible, 1990; McCloskey, Wible, & Cohen, 1988; Pillemer, 1990). McCloskey et al. (1988), for example, found evidence that some flashbulb memories are quite inaccurate and that the kinds of forgetting and distortion evident in flashbulb memories can be predicted on the basis of traditional studies of ordinary memory.

Weaver (1993) reported on a relevant and well-timed study of flashbulb memories. In January 1991, Weaver asked students enrolled in an upper division psychology class to try to remember, in detail, their very next meeting with their roommate (or friend, if they were living alone). Specifically, students were urged to do their best to remember "all the circumstances surrounding" that meeting (without being told specifically what kinds of things to try to remember). Weaver's intention was to see whether the memories formed of these routine meetings would function in ways similar to flashbulb memories, and he distributed a sealed questionnaire for students to fill out as soon as feasible after the meeting.

As it happened, that very evening the first President Bush announced the initial attacks on Iraq in the Persian Gulf War. Although expected and thus not terribly surprising, it was an event of great consequentiality, especially to people with friends or relatives involved. Thus this event seemed likely to be one for which flashbulb memories would be formed. Weaver, reacting quickly, created another questionnaire asking about their memories of hearing about Bush's announcement. Students filled out this second questionnaire two days later. Weaver (1993) gave similar questionnaires about both memories (bombing of Iraq and meeting with roommate/friend), which students completed in April 1991 (three months after the original events) and January 1992 (one year after the original events).

Weaver found very few differences in accuracy for the two memories (as measured by the degree of correspondence between the January 1991 descriptions and the two subsequent ones). Weaver reported that accuracy for both fell off in an Ebbinghaus-like pattern: less accuracy after 3 months, but relatively little change from 3 months to 12 months. What did differ, however, was students' confidence in their memories. Students were much more confident in their memories of the Persian Gulf bombing than in their memory for meeting their friend or roommate. However, the increased confidence did not lead to increased accuracy.

Weaver (1993) concluded that no "flash" is necessary to form a flashbulb memory: Having an intention to remember a particular meeting or event seems enough to ensure forming some memory of it. The "flash," he concluded, affects only our confidence in our memory. What makes flashbulb memories special, he argued, is in part the "undue confidence placed in the accuracy of those memories" (p. 45). Although this last assertion is sure to be controversial, probably no cognitive psychologist would disagree with another of Weaver's conclusions: "Flashbulb memories for exceptional events will continue to be studied, for obvious and interesting reasons. They are rare, unique, and universal" (p. 45). However, Weaver and others reject the idea that flashbulb memories rely on special memory mechanisms.

Eyewitness Memory

Imagine yourself a juror assigned to a robbery/murder case. The defendant, a young man, is alleged to have robbed and killed a convenience store clerk at gunpoint at around 11 P.M. No physical evidence (such as fingerprints or fiber samples) links the defendant to the crime. Instead, the case hinges on the sworn testimony of a convenience store patron who insists that the defendant is the man she saw on the night in question. In cross-examination, the defense

attorney gets the witness to agree that the lighting was poor, the robber was wearing a stocking cap over his face, she was nervous and paying more attention to the gun than to the face of the robber, and so on. Nevertheless, the witness remains convinced that the defendant is the man she saw that night rob and murder the store clerk.

How much would the eyewitness testimony convince you of the defendant's guilt? Elizabeth Loftus, a cognitive psychologist specializing in the study of **eyewitness memory,** would argue that the testimony would have a disproportionate effect on your behavior. She stated (Loftus, 1979) that "eyewitness testimony is likely to be believed by jurors, especially when it is offered with a high level of confidence," even when the confident witness is inaccurate. Indeed, she believed that "all the evidence points rather strikingly to the conclusion that there is almost nothing more convincing than a live human being who takes the stand, points a finger at the defendant, and says 'That's the one!'" (p. 19). Several studies Loftus reviewed, however, suggest that confidence in eyewitness testimony may be far too strong.

In one study, for example, participants viewed a series of slides depicting a (simulated) automobile accident. The automobile, a red Datsun, came to either a stop sign (for half the participants) or a yield sign (for the other half) before becoming involved in an accident with a pedestrian. The experimental

Dennis MacDonald/PhotoEdit

Although eyewitness testimony often has dramatic effects on jurors' decision making, research suggests it is not always accurate.

manipulation came in the questioning that followed the slide show. About half the participants (half of whom had seen a stop sign; the other half, a yield sign) were asked, "Did another car pass the red Datsun while it was stopped at the stop sign?" The other half of the participants were asked, "Did another car pass the red Datsun while it was stopped at the yield sign?" After answering these and other apparently routine questions, participants worked on an unrelated activity for 20 minutes. Then they were given a recognition test of several slides. Included in the test was a critical test pair depicting a red Datsun stopped either at a stop sign or at a yield sign. Participants were to decide which of the two slides they had originally seen. Those who received a question consistent with the slide originally seen (for example, a question about the stop sign when the slide they had previously seen contained a stop sign, not a yield sign) correctly recognized the slide 75% of the time. Participants who received an inconsistent question, however, had an overall accuracy rate of 41%, a dramatic decrease given that guessing alone would have produced an overall accuracy rate of 50%.

Other studies by Loftus (1975) have demonstrated that people's memories can apparently be altered by presenting misleading questions. For example, some participants viewed a film and were then asked, "How fast was the white sports car going when it passed the barn while traveling along the country road?" Other participants were merely asked, "How fast was the white sports car going while traveling along the country road?" Actually, no barn was presented in the film. One week later, all participants were asked whether they had seen a barn. Fewer than 3% of the participants in the second condition reported having seen a barn, whereas 17% of the participants who had been asked the misleading question reported having seen a barn. Lane, Mather, Villa, and Morita (2001) found that experimental "witnesses" who were asked to focus on specific details of a videotaped crime were more likely to confuse what they'd witnessed with the information given them in postevent questions than were "witnesses" asked only to summarize the major aspects of the crime.

"Memory malleability" fits well with some laboratory studies of sentence recall; both support Bartlett's conception of memory as a constructive process. A classic study by Bransford and Franks (1971) illustrates this idea. They gave participants a list of sentences, all derived from four basic sentences, such as "The ants were in the kitchen," "The jelly was on the table," "The jelly was sweet," and "The ants ate the jelly." The sentences the participants saw included two of the preceding sentences, combinations of two of the simple sentences (for example, "The sweet jelly was on the table"), and combinations of three of the simple sentences (example, "The ants ate the sweet jelly on the table"). On a later recognition test, the participants were asked to decide, for each sentence presented, if they had seen that exact sentence before and to

rate their confidence in their judgment. They were most confident in "recognizing" the sentence that combined all four of the simple sentences, "The ants in the kitchen ate the sweet jelly that was on the table," even though it had never been presented.

Bransford and Franks (1971) explained that the participants had not stored a copy of the actually presented sentences in memory. Instead, they had abstracted and reorganized the information in the sentences, integrating the ideas and storing the integration. The participants later could not distinguish between the presented sentences and their own integration. One might argue this is just what Loftus's participants were doing: integrating the original memories with later questions. If the later questions were misleading, that incorrect information became integrated with the original memory to produce a distorted memory.

Recent work in cognitive psychology laboratories has focused on how to improve the chances of accuracy in eyewitness identification. Wells (1993) reviewed some of the findings and made specific suggestions on how police might set up lineups and photo lineups so as to reduce the chances of eyewitness error. For example, he suggested having "mock" witnesses, people who were not present during the crime but who have been given limited information about the crime. The logic here is that the mock witnesses should be equally likely to choose any of the people in a lineup. If, however, the mock witnesses all "identify" the actual suspect, that gives some evidence that the lineup has been put together in a biased way. Other investigators have offered other suggestions for how to decrease eyewitness suggestibility (Chambers & Zaragoza, 2001), such as warning people against being misled by tricky questions.

However, there remains active and often very sharp debate over how well the findings of laboratory studies can be extrapolated to real-world settings. Typically, research participants view staged events, or even movies or slides of incidents. This may not be very similar to the situation in which a bystander observes an actual robbery, assault, murder, terrorist attack, or other kind of crime. Moreover, it seems quite possible that victims or possible victims of crime may attend to different aspects of the situation than bystanders. Yuille (1993) argued that we need more justification to assume that research participants are subject to the same influences as witnesses (or victims) of real crimes.

The Recovered/False Memory Debate

One of the biggest debates to erupt in cognitive psychology in recent years concerns issues of forgetting, retrieving, and creating autobiographical memories. The debate has far-reaching implications well beyond the boundaries of an experimental laboratory. At stake are issues that touch, and indeed tear apart, the lives of real people. The issues concern whether victims of abuse can and/or do repress memories of incidents of abuse, retrieving these so-called **recovered memories** later in therapy, or whether instead some therapists (in fact, a small minority), misinformed about the workings of memory, inadvertently prompt their clients to create **false memories** of things that never really happened.

Note that the topics of eyewitness testimony and false versus recovered memory share many similarities: Both essentially involve the alleged witnessing of an event, sometimes traumatic, often followed later by newer, distorting information. But differences between the topics should also be kept in mind. In the case of eyewitness testimony, the issue is typically focused on recall for information acquired within the past days, weeks, or months. In the case of false or recovered memories, the issue is whether one can recall information from several years to several decades earlier.

Elizabeth Loftus is again an active participant in the debate over whether such "recalls" represent recovered or false memories. She began a review article (Loftus, 1993) on the phenomenon with an anecdote:

> In 1990, a landmark case went to trial in Redwood City, California. The defendant, George Franklin, Sr., 51 years old, stood trial for a murder that had occurred more than 20 years earlier. The victim, 8-year-old Susan Kay Nason, was murdered on September 22, 1969. Franklin's daughter, Eileen, only 8 years old herself at the time of the murder, provided the major evidence against her father. What was unusual about the case is that Eileen's memory of witnessing the murder had been repressed for more than 20 years.
>
> Eileen's memory did not come back all at once. She claimed that her first flashback came one afternoon in January 1989 when she was playing with her 2-year-old son, Aaron, and her 5-year-old daughter, Jessica. At one moment, Jessica looked up and asked her mother a question like, "Isn't that right, Mommy?" A memory of Susan Nason suddenly just came back. Eileen recalled the look of betrayal in Susie's eyes just before the murder. Later, more fragments would return, until Eileen had a rich and detailed memory. She remembered her father sexually assaulting Susie in the back of a van. She remembered that Susie was struggling as she said, "No, don't" and "Stop." She remembered her father saying "Now Susie," and she even mimicked his precise intonation. Next, her memory took the three of them outside the van, where she saw her father with his hands raised above his head with a rock in them. She remembered screaming. She remembered walking back to where Susie lay, covered with blood, the silver ring on her finger smashed.
>
> Eileen's memory report was believed by her therapist, by several members of her family, and by the San Mateo district attorney's office, which chose

> to prosecute her father. It was also believed by the jury, who convicted George Franklin, Sr., of the murder. The jury began its deliberations on November 29, 1990, and returned its verdict the next day. Impressed by Eileen's detailed and confident memory, they found her father guilty of murder in the first degree. (p. 518)

Loftus went on in her article to examine various questions—among them, how authentic recovered memories are. The idea that memories of traumatic events can be repressed—buried in the unconscious mind for long periods of time, even forever—is a tenet of psychoanalytic forms of therapy dating back to Freud. But from a cognitive psychology perspective, the question is whether such **repressed memories** can be carefully described, documented, and explained.

Loftus (1993) and Lindsay and Read (1994) pointed to advice given in different self-help books, one of the best known being *The Courage to Heal* (Bass & Davis, 1988). That book encourages readers who are wondering whether they have ever been victims of childhood sexual abuse to look for the presence of various symptoms, such as having low self-esteem, depression, self-destructive or suicidal thoughts, or sexual dysfunction. The problem, Lindsay and Read (1994) noted, is that these symptoms can also occur for people who have *not* been victims of abuse; the symptoms are just not specific enough to be diagnostic. In *The Courage to Heal,* Bass and Davis (1988) make a further, very strong claim: "If you are unable to remember any specific instances [of abuse] like the ones mentioned above but still have a feeling that something abusive happened to you, it probably did" (p. 21) and "If you think you were abused and your life shows the symptoms, then you were" (p. 22). The book goes on to recommend that readers who are wondering about their past spend time exploring the possibility that they were abused. It offers techniques for recalling specific memories, such as using old family photographs and giving the imagination free rein, or using a recalled childhood event as a beginning point and then deliberately trying to remember abuse connected with that event.

We have seen earlier that there is plenty of room to doubt the absolute accuracy of people's autobiographical memories, even when people seem very sure of them. Research on eyewitness memory has shown how receptive people can be to postevent suggestions. But is it possible for false "memories"—of events that never happened—to be somehow implanted? Loftus and Pickrell (1995; see also Loftus & Ketcham, 1994, and Loftus, 2000) reported on a study that suggests just such a possibility.

Twenty-four people served as the target research participants. Experimenters first interviewed relatives of the participants (who, to be included in the study, had to be familiar with the participant's early childhood) and from the interviews generated three true events that had happened to the research participant when the latter was age 4 to 6. Relatives were instructed that these events were not to be "family folklore" or to be so traumatic that they would be effortlessly recalled. Relatives also provided details about shopping malls and favorite treats of the research participant when he or she was a 5-year-old.

From the interviews with relatives, experimenters then created false accounts of an event that had never actually happened, in which the target participant had allegedly become lost in a shopping mall at age 5. Included in the accounts were details about the name of the mall that had been the closest one to the participant then, as well as names of family members who plausibly might have accompanied the target participant on the alleged trip. Here is an example of a "false memory" created for a 20-year-old Vietnamese American woman:

> You, your mom, Tien, and Tuan all went to the Bremerton K-Mart. You must have been 5 years old at the time. Your mom gave each of you some money to get a blueberry Icee. You ran ahead to get into the line first, and somehow lost your way in the store. Tien found you crying to an elderly Chinese woman. You three then went together to get an Icee. (Loftus & Pickrell, 1995, p. 721)

Participants were given booklets containing instructions, and four stories. Three of the stories recounted actual events, and the fourth story recounted the false event. Each event was described in about a paragraph, with room left for the participant to describe his or her own recall of the event. One to two weeks later, the participants were individually interviewed about their recollections (again being asked to recall as much as they could about the four "events"); the participants were reinterviewed about two weeks later.

As a group, research participants recalled 68% of the true events. However, when completing the booklets, 29% of the participants (7 out of the 24) "recalled" the false event of being lost in a shopping mall. One of the seven later said she did not recall the false memory at the first interview, but the rest (6, or 25%) maintained at least partial recall of the false event through both interviews. Participants' length of recall (measured in number of words they used to describe events) was higher for the true than for the false memories, and they rated the clarity of their memories as lower for the false than for the true memories.

Loftus and Pickrell (1995) made no explicit claims about how easy it is to induce false memories or about how prevalent such memories are. They took the results as proof that false memories *can* be formed through suggestive questioning, and they offered a speculative account of the mechanism(s) responsible.

> The development of the false memory of being lost may evolve first as the mere suggestion of being lost leaves a memory trace in the brain. Even if the information is originally tagged as a suggestion rather than a historic fact, that suggestion can become linked to other knowledge about being lost (stories of others), as time passes and the tag that indicates that being lost in the mall was

> merely a suggestion slowly deteriorates. The memory of a real event, visiting a mall, becomes confounded with the suggestion that you were once lost in a mall. Finally, when asked whether you were ever lost in a mall, your brain activates images of malls and those of being lost. The resulting memory can even be embellished with snippets from actual events, such as people once seen in a mall. Now you "remember" being lost in a mall as a child. By this mechanism, the memory errors occur because grains of experienced events or imagined events are integrated with inferences and other elaborations that go beyond direct experience. (p. 724)

Other researchers have also been able to induce "recollections" of events that never happened. Hyman, Husband, and Billings (1995), for instance, were able to induce about 25% of their undergraduate participants to falsely "recall" different childhood events: being hospitalized for an ear infection; having a fifth birthday party with pizza and a clown; spilling punch at a wedding reception; being in the grocery store when sprinklers went off; and being left in a parked car, releasing the parking brake, and having the car roll into something. Garry and Wade (2005) induced false memories with both narratives and (doctored) photographs, finding that the narratives were more effective in inducing false memories.

Clancy, Schacter, McNally, and Pittman (2000) reported a study in which a laboratory-based model of a false memory was induced. They made use of what is called the Deese/Roediger–McDermott paradigm, in which a participant is presented with a number of related words—for example, *nap, bed, quiet, dark, snore, dream, pillow, night*. Later, the person is given a recognition test consisting of both these "old" words, and some "new" ones that weren't on the list. Results show that semantically related words, such as *sleep*, are likely to be falsely recognized by up to about 80% of college student participants (Roediger & McDermott, 1995).

Clancy et al. (2000) recruited four groups: a control group of women who had never experienced childhood sexual abuse (CSA); a group of women who had experienced CSA and who had a continuous memory of it; a group of women who believed they had experienced CSA but had no specific memory of it (the "repressed memory" group); and a group of women who claimed to have repressed and then recovered memories of experienced CSA (the "recovered memory" group). The recovered-memory group showed much higher false recognition of the semantically related words than did all other groups. The authors concluded:

> Our experiment concerns false recognition for nontraumatic events; therefore, care must be taken when extrapolating our findings to clinical settings. However, the results are consistent with the hypothesis that women who report recovered memories of sexual abuse are more prone than others to develop certain types of illusory memories. (p. 30)

Not all cognitive psychologists have received the research just described on false memories with complete enthusiasm, however. Pezdek (1994), for example, has argued that just because an explanation exists for how false memories *could* be formed does not mean that false memories, especially for ones as traumatic as childhood abuse, actually *are* formed in this way. By analogy, Pezdek noted that an aeronautical engineering explanation exists for why it is impossible for bumblebees to fly (even though they obviously do). Pezdek cautioned against assuming that "memory recovery therapy" is very widespread and argued that the existing evidence for therapist-implanted memories is quite weak.

In further empirical work, Pezdek and her associates (Pezdek, Finger, & Hodge, 1997; Pezdek & Hodge, 1999) suggested there are limits on the types of memories that can be suggestively implanted. Specifically, they believe events can be implanted only to the degree that there exists "script-relevant" knowledge of the type of event.

In one study, for example, Pezdek et al. (1997) recruited both Catholic and Jewish participants. For each participant, they created false accounts of a Catholic ritual (receiving communion at Mass) and one of a Jewish ritual (participating in Shabbat prayers and ceremony). Neither account included "giveaway" words, such as *host, Mass, challah* (bread), or *menorah.* The prediction was that Catholic participants would not have scripts for Jewish ceremonies and thus that implanting of a false "Shabbat" memory would be much less likely than implanting of a false "communion" memory, with the converse being true for Jewish participants. Again, this is because Catholic participants (recruited from a Catholic high school) could reasonably be expected to have a script for Catholic, but not Jewish, ceremonies, and vice versa for the Jewish participants (recruited from a Jewish high school and from Jewish religious education classes).

Indeed, these were the findings reported. Of 29 Catholic participants, 7 falsely recognized the false Catholic event, compared with only 1 who falsely recognized the false Jewish event. Conversely, 3 (of 32) Jewish participants falsely recognized the Jewish event, and none falsely recognized the false Catholic event. Replicating Loftus and Pickrell's (1995) results, significantly more words were written in the "recalls" of true than of false events, ratings of clarity of the memories were higher for true than for false events, and participants were more confident that with more time they would be able to recall more details about true than about false events (for those who "recalled" false events). Pezdek et al. (1997) argued that these results set boundaries around what kinds of events can be planted in memory, with specific instances of familiar events being particularly susceptible.

Obviously, much more work needs to be done on the issue of whether, how, and when false information can be made a part of one's memory. Loftus and

Pickrell's (1995) and Hyman et al.'s (1995) work is suggestive and provocative, but the question of to what degree they can be generalized remains open. A recent fMRI study (Cabeza, Rao, Wagner, Mayer, & Schacter, 2001) showed that different areas of the brain become activated in a word recognition task with "false" words (ones that were not presented but are semantically related to the "true" words that were). Nonetheless, the extension of findings from word recognition tasks to real-world narrative memory recalls may not be straightforward.

It is becoming clearer to cognitive psychologists that autobiographical memories do not function the way videocameras do, faithfully recording details and preserving them for long-term storage and later review. Instead, human memories are malleable and open to "shaping" by later questioning or information. Just how often such shaping occurs, and by what mechanisms, remain open and exciting questions with important real-world implications and consequences.

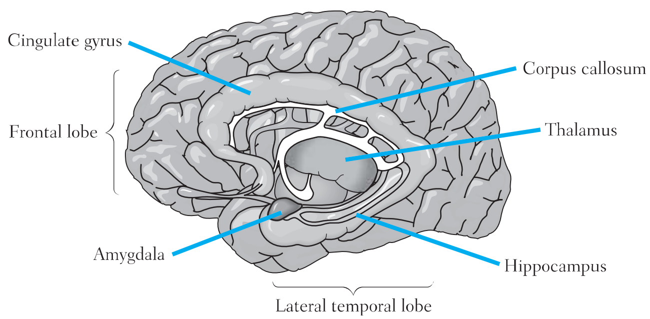
■ AMNESIA

In the preceding sections, we discussed material forgotten from LTM. Here, we pause to take a more detailed look at cases in which people suffer profound impairments in their LTM—people suffering from memory disorders collectively known as **amnesia.** In Chapter 5, we discussed the clinical case study of H.M., a patient who underwent surgery in 1953 that removed many brain structures in the medial temporal lobe region of the brain bilaterally (on both sides), including most of the **hippocampus,** the **amygdala,** and some adjacent areas. As a result, H.M. has suffered since that date from profound amnesia, both for any events after the surgery (anterograde amnesia) and for events that happened within a span of several years before the surgery (Schacter, 1996).

H.M. is not the only person to suffer from amnesia, of course, and over the years neurologists and psychologists have amassed a great number of clinical cases from which to draw generalizations and principles. Amnesia can result from damage either to the hippocampal system (which includes the hippocampus and amygdala) or to the closely related midline diencephalic region (see Figure 6-8). This damage can arise from oxygen deprivation, blockage of certain arteries through a stroke, the herpes simplex encephalitis virus, a closed head injury such as those typically suffered in automobile accidents, Alzheimer's disease, Korsakoff 's syndrome (a disease of chronic alcoholism), certain tumors, or, in the short term, bilateral electroconvulsive shock treatments, or ECT (Cohen, 1997).

FIGURE 6-8 ■ *The network of neural structures underlying our ability to remember and learn. Illustrated here are the structures in the medial temporal lobe, specifically the hippocampal system (which includes the hippocampus, the amygdala, and adjoining cortex) and the midline diencephalic structures, specifically the dorsomedial nucleus of the thalamus, which, when damaged, causes amnesia. For reference, structures outside the system but located nearby (for example, the corpus callosum and the frontal region) are also shown.*

SOURCE: Cohen (1997, p. 319).



The severity of the amnesia varies from case to case, with H.M. exhibiting some of the most severe memory impairments. Some patients recover some memories over time; for example, those undergoing bilateral ECT (a treatment used today for severe forms of depression) recover completely within a few months, and people who suffer a closed head injury likewise often recover some or all of their memories. Some amnesias, such as those brought on by accidents or strokes, have very sudden onsets; others, typically those originating through brain tumors or disease, appear more gradually (Cohen, 1997). Many neuropsychologists make a distinction between anterograde and retrograde amnesia in terms of the way each functions, and we will therefore review each of these in turn.

Anterograde Amnesia

Cohen (1997) noted that the **anterograde** form of amnesia, a memory deficit extending forward in time from the initial point of memory loss, has five principal features. The first is that anterograde amnesia affects LTM but not working memory. We discussed this idea in Chapter 5 in our look at the H.M. case study. Cohen related an illustrative anecdote about a conversation he had with H.M.

> One day during a lengthy car drive to MIT's Clinical Research Center to be tested, H.M. proceeded to tell me about some guns that were in his house (actually, he had them only in his youth). He told me that he had two rifles, one with a scope and certain characteristics, and the other with just an open sight.
>
> He said that he had magazines from the National Rifle Association (actually, just a memory of his earlier family life), all about rifles. But, he went on, not only did he have rifles, he also had some handguns. He had a .22, a .32, and a .44. He occasionally took them out to clean them, he said, and had taken them with him on occasion to a shooting range. But, he went on, not only did he have some handguns, he also had rifles. He had two rifles, one with a scope and the other with an open sight. He had magazines from the National Rifle Association, all about rifles, he said. But, not only did he have rifles, he also had handguns. . . . On and on this went, cycling back and forth between a description of the rifles and a description of the handguns, until finally I derailed the conversation by diverting his attention. (p. 323)

Cohen argued that H.M.'s memory of his handguns and of his rifles were both intact because they derived from his very remote past, several years before his surgery. They were related in his LTM—not surprising, given what researchers know about memory for general knowledge (a topic we will take up in Chapter 7 in greater detail). Thus his discussion of one piece of knowledge called to mind the other. Each piece, however, filled up the working-memory capacity, so that when H.M. finished talking about one, he forgot he had just told about the other.

The second feature is that anterograde amnesia affects memory regardless of the modality—that is, regardless of whether the information is visual, auditory, kinesthetic, olfactory, gustatory, or tactile. Cohen (1997) noted that global anterograde amnesia results from bilateral damage to the medial temporal lobe or midline diencephalic structures; unilateral (one-sided) damage to these areas typically impairs only one kind of memory—for example, either verbal or spatial. Moreover, whether the mode of testing memory is free recall, cued recall, or recognition, the memory of someone with anterograde amnesia is similarly hampered.

Third, according to Cohen (1997) and as illustrated in the story about H.M. and the guns, anterograde amnesia spares memory for general knowledge (acquired well before the onset of amnesia) but grossly impairs recall for new facts and events. Thus H.M. could not report any personal event that had occurred after his surgery, and he performed very poorly on tasks in which he was asked to recall lists of words for any length of time beyond a few minutes. H.M. also had difficulty retaining newly learned pairings of information, such as learning new vocabulary (*jacuzzi, granola,* and other words that came into usage after 1953, the year of his surgery).

A fourth principal feature of anterograde amnesia is that it spares skilled performance. Recall the story of the musician Clive Wearing, described in Chapter 5, who cannot remember much of his own life or remember his wife's frequent visits but can still play the harpsichord and piano and conduct a choir through a complex piece of music. Other studies have shown that amnesic patients can be taught to perform a skill, such as mirror tracing (tracing the outline of a geometric figure that is only visible in a mirror) or a rotary pursuit task (tracking a target that is moving circularly and erratically). H.M. learned the first task and showed a normal learning curve for it, although at each session he denied any previous experience with the task. Cohen and Squire (1980) have shown similar results in teaching amnesic patients and nonamnesic control participants to perform a mirror-image reading task. As the data presented in Figure 6-9 show, the data from the amnesic patients were in many instances virtually identical to those of the control participants.

The fifth principal feature of anterograde amnesia is that even when amnesic patients do learn a skill, they show *hyperspecific* memory: They can express this learning only in a context extremely similar to the conditions of encoding. In a sense, this seems to be a version of the encoding specificity principle carried to the extreme.

Retrograde Amnesia

Loss of memory for information acquired and stored before the onset of amnesia is known as **retrograde amnesia.** Although such loss has some similarities with anterograde amnesia, important differences appear as well. Interestingly, all amnesic patients seem to show at least some retrograde amnesia; they may or may not exhibit anterograde amnesia. Cohen (1997) described four basic features of retrograde amnesia.

The first is that the temporal extent—the time span for which memory is lost—can vary enormously in retrograde amnesia. Patients suffering from Korsakoff's, Alzheimer's, Parkinson's, or Huntington's disease are likely to exhibit temporally extensive amnesia, with loss of memory acquired and stored for several decades. Other patients, such as those who have undergone bilateral ECT or suffered a closed head injury, show temporally limited retrograde amnesia, losing information for a span of only months or perhaps weeks. In many cases, over time the patient either fully (in the case of ECT) or partially recovers the lost memories. Damage to the hippocampal region can also cause retrograde amnesia. H.M.'s retrograde amnesia was found to cover a span of 11 years, less than for some other cases reported in the literature.

A second feature of retrograde amnesia is observable when scientists examine which particular memories are lost. Figure 6-10 plots some relevant data. Patients undergoing ECT treatments were asked to recall information about

FIGURE 6-9 ■ *(FACING PAGE) An example of a spared perceptual skill in patients with amnesia. (A) Examples of the mirror-image word triads used in a mirror-image reading task (Cohen & Squire, 1980). (B) Just like control individuals, patients who have amnesia from different causes—patient N.A., who has midline diencephalic damage (top); patients with Korsakoff's amnesia (middle); and patients who underwent electroconvulsive therapy (ECT) (bottom)—increased the speed with which they could read the triads. This increase occurred not only for repeated triplets (triplets that they saw before; graphs on the right) but also for new (nonrepeated) triads (graphs on the left). The increase in the reading times for novel triplets indicates that the patients with amnesia were learning the perceptual skill of mirror-image reading.*

SOURCE: Cohen (1997, p. 330).

television shows that had aired for a single season only (that way, the experimenters knew precisely when the memories were formed; this study was conducted well before the proliferation of cable channels!). Before the ECT treatments, the patients were best at recalling facts from very recently aired shows, as you would be. After the ECT treatments, however, these same patients' data showed a temporal gradient, with the most recent memories being the most likely to be lost (Cohen, 1997).

In the case of ECT patients, we would expect full recovery, in time, of the lost memories. With patients suffering from a closed head injury, the story is a little different. There, the temporal extent of the retrograde amnesia often shrinks slowly over time, with the most remote memories being the most likely to return. For example, initially the retrograde amnesia might span several years before the head trauma occurred; after a year in recovery, the total span of retrograde amnesia might be the two weeks immediately preceding the trauma.

Cohen (1997) described a third feature of retrograde amnesia: It typically spares information that was "overlearned" before the onset.

> Despite their extensive retrograde amnesias, patients with amnesia associated with Korsakoff's disease, anoxia, or encephalitis have intact knowledge about the world; preserved language, perceptual, and social skills; and spared general intelligence. Only the extensive retrograde amnesias associated with progressive dementias, as in Alzheimer's disease or Huntington's disease, impair this kind of information, and then only later in the progression of the disease. (p. 339)

Finally, as with anterograde amnesia, retrograde amnesia seems not to affect skill learning, such as mirror tracing. Even when patients cannot remember ever having practiced the skill, their performance still seems to show normal rates of improvement (Cohen, 1997).

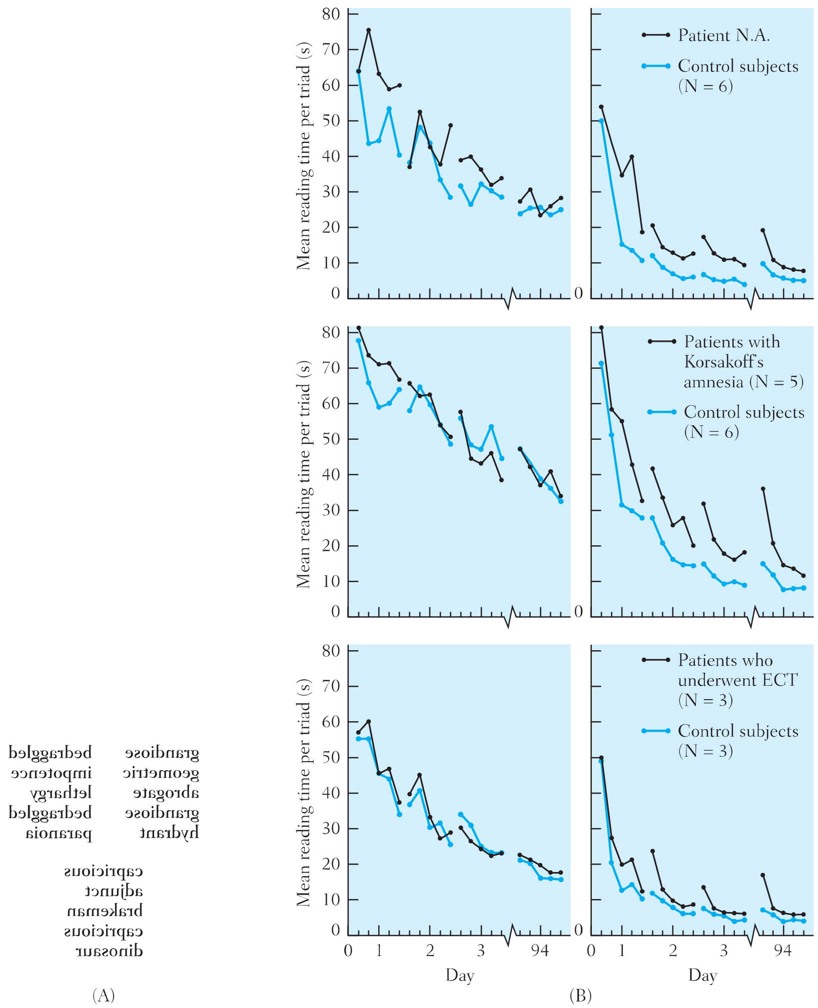
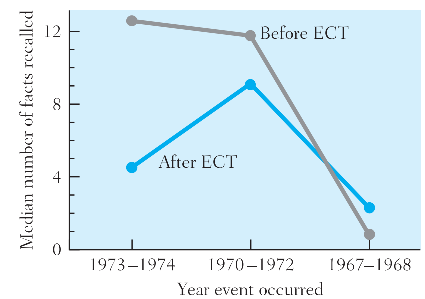


FIGURE 6-10 ■ *Evidence of temporally limited retrograde amnesia in patients who have undergone electroconvulsive therapy (ECT). Before and after a series of ECT treatments, 20 individuals were asked to recall information about former television programs that aired for just one season. Shown here is a graph of the median number of facts recalled. Before ECT, patients showed a normal forgetting curve; their best recall was for shows from the most recent time period, and their poorest recall was for shows from the most remote time period. After ECT, a selective impairment occurred in the recall of shows from the most recent time period.*

SOURCE: Cohen and Eichenbaum (1993).



Many neuropsychologists believe the study of amnesia supports some specific ideas about the organization of memory in general. That amnesia can disrupt long-term memory without any impairment in working memory provides some support for considering these as two distinct types of memory. That retrograde amnesia covers a defined time span and shows a temporal gradient implies that even after being formed, new memories continue to undergo neurological change for some period of time, perhaps years. That some kinds of information (personal memories, memories for events or random tidbits of information) are lost in amnesia and others are not (such as overlearned and well-practiced information and skills) has suggested many different kinds of memory systems to some (though not all) psychologists, as we will see in Chapter 7. Finally, there is a strong suggestion that the structure in the brain known as the hippocampus plays a very important role in the retrieval of memories for information, although clearly not all long-term memories require involvement of the hippocampus (otherwise, amnesic patients would never recall any previously learned information).

McGaugh (2000) notes that studies of amnesic patients also tell us something about **memory consolidation,** a process originally proposed a century ago. The idea is that new information "initially persist[s] in a fragile state and consolidate[s] over time" (p. 248). Blows to the head disrupt this process, causing newly learned information to be lost. Some of McGaugh's work suggests an important role for the amygdala, a structure we discussed earlier, in the memory consolidation process.

Throughout this chapter, we've been focusing on memory for specific events (such as hearing a particular word list or witnessing a crime). Often, however, our memories of a particular event call on our memories of general knowledge. For example, if I were to recall the last lecture I gave, I might use my general knowledge about lectures (where students sit or the kinds of equipment, such as chalk or overhead projectors, that I typically use) to reconstruct my memory of that particular class. In the next chapter, we will examine more closely the ways in which this general knowledge is stored and organized.

As stated before, memory touches just about every cognitive activity we can think of. Thus it should come as no surprise that memory bears on many other chapters in this book. In particular, in Chapter 7 we will take up the question of different memory systems, especially as they pertain to our memory for general knowledge. Chapter 8 will continue the discussion of memory for general knowledge as we look specifically at how we form new concepts. In Chapter 9, when we discuss visual imagery, we will come back to issues of how information is encoded and mentally represented. We will see in other chapters that memory plays a significant role in almost every instance of cognitive processing. Thus, as new research on the topic of memory changes our conceptions of how it works, we can expect new developments in almost every other area of cognition.

SUMMARY

1. We've seen in this chapter, as well as in Chapter 5, that cognitive psychologists approach the study of memory in a variety of ways and that this diversity dates back at least to "founding" cognitive psychologists such as Ebbinghaus and Bartlett. Some of the diversity arises in theoretical orientations: Some psychologists seek evidence for the proposition that there are different memory *stores* (for example, sensory memory, STM, LTM), whereas others focus on the kind of processing done with to-be-remembered information.
2. Within the modal model of memory, LTM is described as the storage of vast amounts of information, usually coded by meaning, for durations ranging up to several decades if not indefinitely.
3. Theories of forgetting from LTM emphasize interference as a very important mechanism. An elaboration of this idea is that when retrieval cues become linked to multiple targets, they become less reliable in the person's ability to pick out a given target.

4. Retrieval of information is made easier when the information to be retrieved is categorized, when the retrieval cues match the cues that were available at the time of encoding (the encoding specificity principle), and when the retrieval cues are very distinctive.
5. Consistent with the encoding specificity principle, investigators have found that recall (but not recognition) is made easier when the recall context is the same as the learning context (the context effect), when the pharmacological state of the person at recall matches his or her pharmacological state during encoding (the state-dependent learning effect), and, under some conditions, when the person's mood at the time of recall matches his or her mood at the time of learning (the mood-dependent memory effect). Recall is also enhanced when material is learned in several temporally spaced sessions as opposed to one long learning session (the spacing effect).
6. Work on the levels-of-processing theory has demonstrated that the more active and meaningful the original processing of information, the more memorable the information will be. This idea has obvious and practical relevance for students: If you want to improve your recall of material for later testing (in midterms and finals), organize it and think about its meaning (deep processing) rather than merely reading, underlining, or highlighting the words (shallow processing).
7. The work reported here on people's recall of their own life events dovetails in several ways with the laboratory-based investigations of memory described in this chapter and the last. Some of the findings that have emerged—for example, the constructive nature of recall—fit well with laboratory findings. However, different results are found in laboratory- and everyday-based studies. Autobiographical recall seems better than recall of laboratory stimuli, but whether different cognitive mechanisms are at work remains an open question.
8. Work on flashbulb and eyewitness memories suggests that people's recollections of moments of their past can be wrong, even when those people seem absolutely convinced of the accuracy of the memory. This suggests that our own confidence in our memories may sometimes be too high; at the very least, there are probably occasions when we are both very sure of our memories and also very wrong. Work on eyewitness testimony suggests that memory traces of a witnessed event are very malleable and subject to disruption by postevent leading questions.
9. Debates over whether memory traces can be repressed for long periods of time, then recalled, have erupted in recent years. Some studies purport to show that under repeated urgings, people can be induced to "recall" emotional events that never happened. One study suggests there may well be limits to the types of "false" memories that can be so implanted, but as yet we do not have a firm understanding of what these limits are.

10. Neuropsychologists who study memory deficits recognize two different kinds of amnesia. Both seem to involve damage to either the hippocampal system or the midline diencephalic region. This damage can arise in several different ways: through closed head injury, a stroke, oxygen deprivation to the brain, bilateral electroconvulsive shock treatments, a virus such as encephalitis, or other diseases such as Alzheimer's or Korsakoff's.
11. Anterograde amnesia, which extends forward in time from the onset of amnesia, selectively affects long-term (but not working) memory, regardless of modality or type of memory test, and spares memory for general knowledge and skilled performance (although the learning of the latter will not be explicitly remembered) but can result in memories for skills that are hyperspecific to the original learning context and cannot be transferred to other, similar contexts.
12. Retrograde amnesia, the loss of memory acquired and stored before the point of onset, is almost always a component of amnesia. The temporal extent of the amnesia varies in different patients; it is worst for memories of information acquired closest to the point of onset. Some recovery of some of the lost retrograde memories is often possible. Retrograde amnesia also spares material that has been "overlearned" before the onset, including such things as language, general knowledge, and perceptual and social skills. As with anterograde amnesia, retrograde amnesia seems to spare skill learning.

Review Questions

1. In what ways do the underlying assumptions of the levels-of-processing theory differ from the underlying assumptions of the modal model?
2. Describe the different kinds of interference and how they are theorized to operate.
3. Describe and evaluate encoding specificity as a principle of retrieval of information. How does it relate to such phenomena as the spacing effect, state-dependent learning, and context effects on retrieval?
4. Explore the interrelationships among the context effect, the state-dependent learning effect, the mood-dependent memory effect, and the spacing effect.
5. Apply the cognitive research on memory to the practical problem of giving a college student advice about how to study for an upcoming midterm. What advice would you give, and which principles would this advice draw on?
6. What do the findings of Linton and Brewer suggest about the workings of autobiographic memory for ordinary events?

7. How do findings from the eyewitness testimony and the flashbulb memory literature fit with laboratory-based findings reported earlier? What are the differences, if any?
8. Is there a need to posit special mechanisms for flashbulb memories? Defend your view.
9. Describe the debate over "recovered" versus "false" memories of traumatic events. What are the most important issues for cognitive psychologists to address, and what issues (pragmatic, ethical, theoretical) are they likely to face in doing so?
10. Review the similarities and differences between anterograde and retrograde amnesia.
11. What exactly do findings from memory studies with amnesic patients tell us about the way memory operates in nonamnesic people? (*Note*: This question is a controversial one within the field—can you see why?)

Key Terms

amnesia
amygdala
anterograde amnesia
autobiographical memory
context effect
cue overload
encoding specificity
encoding variability
eyewitness memory
false memory
fan effect
flashbulb memory
hippocampus
incidental learning
levels-of-processing theory of memory
memory consolidation
mnemonics
mood-dependent memory effect
paired associates learning
recovered memory
repressed memory
retrieval cue
retroactive interference
retrograde amnesia
schemata
spacing effect
state-dependent learning
state-dependent memory

CogLab Demonstrations

To check your knowledge of the key concepts in this chapter, take the chapter quiz at http://www.thomsonedu.com/psychology/galotti. Also explore the hot links that provide more information.

Two CogLab demonstrations are relevant to topics discussed in this chapter. The first is **Serial Position,** which provides experience with this phenomenon. In the discussion of false memories, mention was made of the Deese/Roediger–McDermott paradigm, which is shown in the **False Memory** demonstration.

Web Resources

Visit our website. Go to http://www.thomsonedu.com/psychology/galotti, where you will find online resources directly linked to your book, including quizzes, flashcards, crossword puzzles, and glossaries.

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Representation and Organization of Knowledge

PART

III

CHAPTER

7

Memory for General Knowledge

As a psychologist, teacher, and amateur dog trainer, I have a great deal of mentally stored knowledge about different topics. I often surprise my students (and sometimes myself) by remembering the approximate title, author, journal, and year of an article that would complement their independent study projects. Less often, when I teach dog obedience classes and am stumped by a dog who just can't seem to learn a simple task, I can call up from memory an idea I heard about years ago at a dog-training seminar. Obviously, when I remember or recall these pieces of information I am using my memory.

How do I hold onto information in such a way that I can access it, sometimes years after I've stored it? Consider the vast range of information everyone must have stored in permanent memory. In addition to information regarding events in your life (your sixth birthday party, the time you broke your arm, going to the circus, your first day of junior high), you have also stored a great deal of knowledge: definitions of the words you know; arithmetic facts and procedures; historical, scientific, and geographic knowledge; and (I hope) even some knowledge of principles of cognitive psychology. In this chapter, we will take a more detailed look at this kind of permanent memory—memory for knowledge and information.

One question that will concern us is how stored knowledge is organized. There are several distinct ways of arranging and storing information, and each has different implications for ease of access and retrieval. An analogy to your bookshelves may help. Think about your books and how they are arranged. You may have a section for textbooks, a section for nonfiction, a section for mysteries, and a section for trashy romances. Or you may have all the books arranged alphabetically by author. Or you may have tall books on one shelf, paperbacks on another. Each possibility represents a different way of organizing.

Each possibility has different implications for how you look for a particular book and how easy it is to find it. Suppose you want to find *Gone with the Wind,* but you've forgotten the author's name. If you've arranged your books alphabetically by author, you'll have a much more difficult time than if you've arranged them by title or by category. A variety of models have been proposed for how our knowledge is mentally represented and organized. Each makes different predictions about how we search for particular pieces of information.

To start, do your memories of specific events (say, your sixth birthday party) differ in important ways from your memories of general knowledge (for example, that 2 + 2 = 4)? Endel Tulving (1972, 1983) drew a distinction between memories for events and memories for general knowledge. He argued that long-term memory consists of two separate and distinct yet interacting systems.

One system, **episodic memory,** holds memories of specific events in which you yourself somehow participated. The other system, **semantic memory,** holds information that has entered your general knowledge base: You can recall parts of that base, but the information recalled is generic—it doesn't have much to do with your personal experience. For example, your memory that Sigmund Freud was a founding practitioner of psychoanalysis is presumably in your general knowledge base but divorced from your personal memories of what happened to you at a certain time. It's probable, actually, that you can't even remember when the fact about Freud entered your memory.

Contrast this situation with when information about your first date or the 9/11 attacks on the World Trade Center and Pentagon entered your memory. For those instances you may recall not only the information itself but also the circumstances surrounding your acquisition of the information (where, when, why, how, and from whom you heard, saw, or otherwise acquired it), as we saw in Chapter 6.

After reviewing arguments and evidence for the episodic/semantic distinction, we'll go on to concentrate on semantic memory. Specifically, we'll look at

a number of proposals for how our knowledge base or bases are organized and the implications that organization has for the ways we access information.

Finally, we'll review some work suggesting that some of our memories are not accessible to our conscious recollection. Some psychologists use the term *implicit memory* to describe phenomena in which some experiences leave memory traces without our being aware of them; we know these traces exist, however, when they are shown to influence our behavior later. Work with amnesic patients will be relevant to our understanding here once again. We will see that much of the work on implicit memory is carried out within a semantic memory framework.

■ THE SEMANTIC/EPISODIC DISTINCTION

Tulving (1972, 1983, 1989) proposed a classification of long-term memories into two kinds: episodic and semantic. Episodic memory is memory for information about one's personal experiences. As Tulving (1989) put it, episodic memory "enables people to travel back in time, as it were, into their personal past, and to become consciously aware of having witnessed or participated in events and happenings at earlier times" (p. 362). Episodic memory has also been described as containing memories that are temporally dated; the information stored has some sort of marker for when it was originally encountered.

Any of your memories that you can trace to a single time are considered to be in episodic memory. If you recall your high school graduation, or your first meeting with your first-year roommate, or the time you first learned of an important event, you are recalling episodic memories. Even if you don't recall the exact date or even the year, you know the information was first presented at a particular time and place, and you have a memory of that presentation.

Semantic memory, in contrast, is thought to store general information about language and world knowledge. When you recall arithmetic facts (for example, "2 + 2 = 4"), historical dates ("In fourteen hundred and ninety-two, / Columbus sailed the ocean blue"), or the past tense forms of various verbs *(run, ran; walk, walked; am, was),* you are calling on semantic memory.

Notice in these examples that in recalling "2 + 2 = 4," you aren't tracing back to a particular moment when you learned the fact, as you might do with the 9/11 attacks. Instead of "remembering" that 2 + 2 = 4, most people speak of "knowing" that 2 + 2 = 4. This distinction between memories of specific moments and recall from general knowledge marks the major difference between semantic and episodic memory. Why make such a distinction? Doing so captures our intuition that the recall of some things differs from the recall of others. Recalling your graduation simply has a different "feel" from recalling the sum of 2 and 2.

Tulving (1972, 1983, 1989) described episodic and semantic memory as **memory systems** that operate on different principles and hold onto different kinds of information. Tulving (1983) pointed to a number of differences in the ways episodic and semantic memory seem to work, and I'll describe a few of the major differences here.

As we have just discovered, the nature of the information thought to be held in the two memory systems is different. In episodic memory, we hold onto information about events and episodes that have happened to us directly. In semantic memory, we store knowledge: facts, concepts, and ideas. With episodic memory, the memories are encoded in terms of personal experience. Recalling memories from the episodic system takes the form of "Remember when . . . ." With semantic memory, the information is encoded as general knowledge, context effects are less pronounced, and retrieval of information consists of answering questions from our general knowledge base in the form of "Remember what . . . ." Organization of episodic memory is temporal; that is, one event will be recorded as having occurred before, after, or at the same time as another. Organization of semantic memory is arranged more on the basis of meanings and meaning relationships among different pieces of information.

Schacter (1996) offered a number of case studies of people suffering from different kinds of amnesia that support the episodic/semantic distinction. Gene, for example, survived a motorcycle accident in 1981 (when he was 30 years old) that seriously damaged his frontal and temporal lobes, including the left hippocampus. Gene shows anterograde amnesia and retrograde amnesia. In particular, Gene cannot recall *any* specific past events, even with extensive, detailed cues. That is, Gene cannot recall any birthday parties, school days, or conversations. Schacter noted further that "even when detailed descriptions of dramatic events in his life are given to him—the tragic drowning of his brother, the derailment near his house, of a train carrying lethal chemicals that required 240,000 people to evacuate their homes for a week—Gene does not generate any episodic memories" (p. 149).

In contrast, Gene recalls many facts (as opposed to episodes) about his past life. He knows where he went to school; he knows where he worked. He can name former coworkers; he can define technical terms he used at the manufacturing plant where he worked before the accident. Gene's memories, Schacter argued, are akin to the knowledge we have of other people's lives. You may know, for example, about incidents in your mother's or father's lives that occurred before your birth: where they met, perhaps, or some memorable childhood incidents. You know *about* these events, although you do not have specific *recall* of them. Similarly, according to Schacter, Gene has *knowledge* of some aspects of his past (semantic memory), but no evidence of any *recall* of specific happenings (episodic memory).

Schacter (1996) also described neuropsychological case studies of people with deficits that are "mirror images" of Gene's. A case was reported, for instance, of a woman who, after a bout of encephalitis and resultant damage to the front temporal lobe,

> no longer knew the meanings of common words, had forgotten virtually everything she once knew about historical events and famous people, and retained little knowledge of the basic attributes of animate and inanimate objects. She had difficulty indicating the color of a mouse, and had no idea where soap would ordinarily be found. . . . However, when asked about her wedding and honeymoon, her father's illness and death, or other specific past episodes, she readily produced detailed and accurate recollections. (p. 152)

These two cases, and others like them (some described by Schacter, 1996; see also Riby, Perfect, & Stollery, 2004), provide some clinical neuropsychological evidence supporting the idea that episodic memory and semantic memory operate independently. That is, the existence of people in whom one type of memory seems seriously impaired while the other appears spared gives concrete evidence for the existence of two separate systems of memory.

Tulving (1989) also reported some cases in which the cerebral blood flow patterns were different when volunteer participants were asked to lie quietly and retrieve either an episodic or a semantic memory. Episodic retrieval tended to be associated with more frontal lobe activity than did semantic memory. Unfortunately, not all participants showed these effects; some showed no discernible differences, making any straightforward interpretation of these results impossible as of yet. Other work has suggested that different neural areas are activated during episodic versus semantic memory retrieval, although the patterns of neural activity underlying different kinds of memory retrieval share similarities and are not completely distinct (Menon, Boyett-Anderson, Schatzberg, & Reiss, 2002; Nyberg, Forkstam, Petersson, Cabeza, & Ingvar, 2002). A recent study suggests that atrophy of the perirhinal cortex in the temporal lobe and directly connected areas affects semantic but not episodic memory (Davies, Graham, Xuereb, Williams, & Hodges, 2004).

Tulving's (1972, 1983, 1989) proposals have provoked strong controversy within the field of cognitive psychology. McKoon, Ratcliff, and Dell (1986) presented a series of arguments centering on the usefulness of considering episodic and semantic memories to be two separate memory *systems* and on the kind of evidence needed to support the distinction. Many psychologists find it hard to draw sharp lines between knowledge that includes information about the time it was first learned and knowledge that is more "generic" in character (Baddeley, 1984). However, almost everyone agrees that at the very least there seem to be two kinds of memories—semantic and episodic—even if they are stored within a single system. Most of the topics covered in Chapters 5 and 6 had to do with episodic memory. After all, when participants in an experiment are given a list of words to remember, they are later asked to recall *those* words, which they memorized at a particular time, not just any words they happen to know. In the rest of this chapter, we will concentrate on semantic memory, considering the way general knowledge is stored, processed, and retrieved.

Semantic memory is thought to have enormous capacity; hence, it is important to know how such memory is organized. We've already discussed the library analogy for semantic memory. This metaphor grows out of an information-processing paradigm, which sees memory as consisting of one or more distinct storage areas. If a library (storage area) contains only a handful of books, it makes little difference how they are arranged or stored; it would be an easy matter for a patron looking for a particular book simply to browse through the entire collection. As the number of books grows, however, the need for some sort of organizational system becomes pressing. One might say knowledge bases are comparable to a large library; therefore, understanding their organization is crucial for understanding how we retrieve and use information. Later we will see that connectionist models view the organization of knowledge very differently, and reject this library metaphor.

■ SEMANTIC MEMORY MODELS

Many of the semantic memory models developed because psychologists and computer scientists interested in the field of artificial intelligence wanted to build a system having what most people refer to as "commonsense knowledge." The premise was that associated with your knowledge of an explicit fact is a great deal of implicit knowledge, information you know but take for granted.

Here's an example of implicit knowledge in our understanding of everyday routines. Consider the typical directions on a shampoo bottle: "Wet hair. Apply shampoo. Lather. Rinse. Repeat." If you slavishly followed these directions, you would emerge from the shower only when the bottle was empty! However, most of us do manage a shampoo, even before our first cup of coffee. What we rely on is not just the directions but our world knowledge or common sense that one or two repetitions of the lather–rinse cycle are sufficient (Galotti & Ganong, 1985).

Our vast knowledge of language and concepts also appears to have associated with it a great deal of implicit knowledge. For instance, if I asked you, "Does a Bernese mountain dog have a liver?" you would very likely answer yes (correctly). Your answer comes (I assume) not from your extensive study of Bernese mountain dogs but from your knowledge that Bernese mountain dogs are dogs, dogs are mammals, mammals have livers. In this section, we will consider models of how knowledge is represented in semantic memory such that we can make these inferences and demonstrate our common sense.

To build such models, we need to make a number of inferences about our mental representations of information from our performance on specific tasks. For example, if we can retrieve some information very quickly (say, think of words beginning with the letter *L*) relative to other information (say, think of words with *L* as the fourth letter), that suggests something about the organization of knowledge. In this example, for instance, we can infer that our **lexicons,** or mental dictionaries, are organized by the first letter, not the fourth, in a word. In the specific models presented next, you'll see that the tasks invented were meant to answer very specific questions about the nature of the mental organization of information.

Many of the models described in this chapter were developed in the 1970s, when information-processing analogies between humans and computers were dominating the field of cognitive psychology. We will review some of these "classic" models first, before turning our attention to connectionist models that make quite different assumptions about the representation and organization of knowledge.

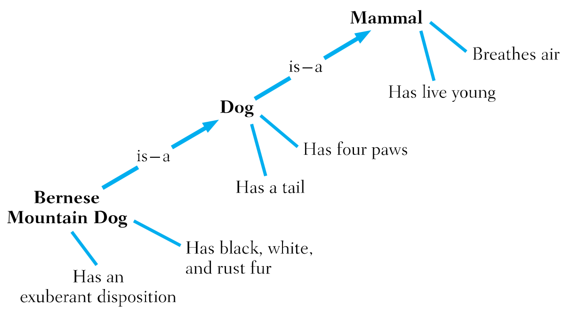
The Hierarchical Semantic Network Model

Because our world and language knowledge is so great, the storage space requirements to represent it are large. Computer scientists trying to create databases of knowledge decades ago were quite constrained by the very limited memory available to computers of that day, so the models of semantic memory may well have been shaped by this constraint.

One way to conserve memory space would be to try to avoid storing redundant information wherever possible. Therefore, rather than storing the information "has live young" with the mental representation for Bernese mountain dog and again with the mental representations for human, lion, tiger, and bear, it makes more sense to store it once, at the higher-level representation for mammal. This illustrates the principle of **cognitive economy:** Properties and facts are stored at the highest level possible. To recover information, you use inference, much as you did to answer the earlier question about Bernese mountain dogs' having livers.

A landmark study on semantic memory was performed by Collins and Quillian (1969). They tested the idea that semantic memory is analogous to a network of connected ideas. As in later connectionist networks, this one consists of nodes, which in this case correspond roughly to words or concepts. Each node is connected to related nodes by means of *pointers,* or links that go from one node to another. Thus the node that corresponds to a given word or concept, together with the pointers to other nodes to which the first node is connected, constitutes the semantic memory for that word or concept. The collection of nodes associated with all the words and concepts one knows about is called a **semantic network.** Figure 7-1 depicts a portion of such a network for a person (such as me) who knows a good deal about Bernese mountain dogs. Readers familiar with computer science may be reminded of linked lists and pointers, a metaphor that Collins and Quillian intended.

FIGURE 7-1 ■ *Partial semantic network representation for Bernese mountain dog.*



Collins and Quillian (1969) also tested the principle of cognitive economy, just described. They reasoned that if semantic memory is analogous to a network of nodes and pointers and if semantic memory honors the cognitive economy principle, then the closer a fact or property is stored to a particular node, the less time it should take to verify the fact and property. Collins and Quillian's reasoning led to the following prediction: If a person's knowledge of Bernese mountain dogs is organized along the lines of Figure 7-1, he or she should be able to verify the sentence "A Bernese mountain dog has an exuberant disposition" more quickly than to verify "A Bernese mountain dog has live young." Note that the property "has an exuberant disposition" is stored right with the node for Bernese mountain dog, indicating that this property is specific to this kind of animal. The property "has live young" is not specific to Bernese mountain dogs, so it is stored a number of levels higher in the hierarchy.

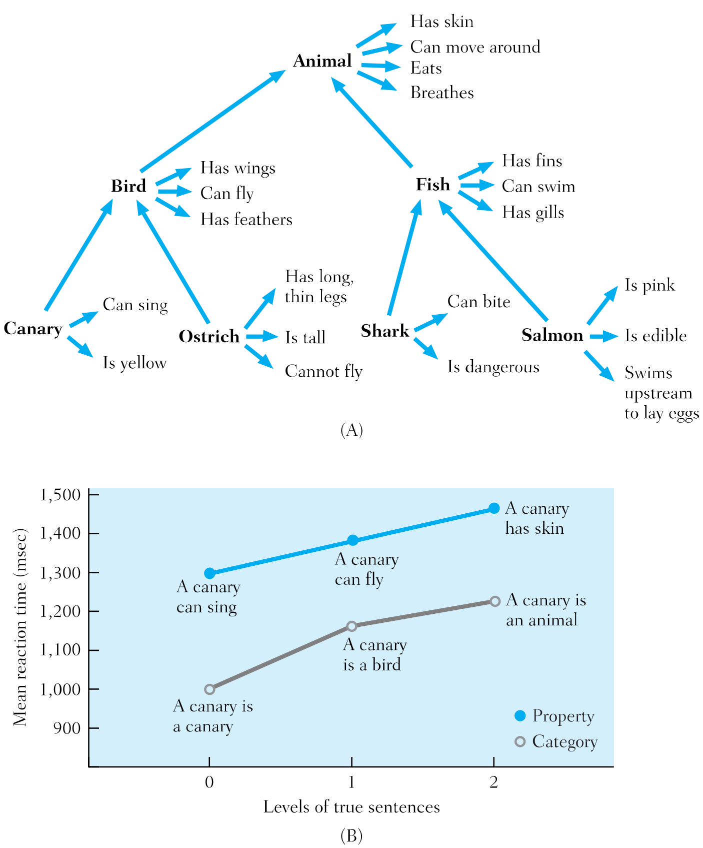
In their study (see Figure 7-2), Collins and Quillian (1969) presented people with a number of similar sentences, finding, as predicted, that it took people less time to respond to sentences whose representations should span two levels (for example, "A canary is a bird") than they did to sentences whose representations should span three (for example, "A canary is an animal").

The model was called a **hierarchical semantic network model of semantic memory,** because researchers thought the nodes were organized in hierarchies. Most nodes in the network have superordinate and subordinate nodes. A superordinate node corresponds to the name of the category of which the thing corresponding to the subordinate node is a member. So, for example, a node for "cat" would have the superordinate node of "animal" and perhaps several subordinate nodes, such as "Persian," "tabby," and "calico."

Meyer and Schvaneveldt (1971) performed a series of experiments that elaborated the semantic network proposal. They reasoned that if related words are stored close by one another and are connected to one another in a semantic network, then whenever one node is activated or energized, energy spreads to the related nodes, as in Figure 7-3. They demonstrated this relationship in a series of experiments based on **lexical decision tasks.** In this kind of experiment, participants see a series of letter strings and are asked to decide, as quickly as possible, if the letter strings form real words. Thus they respond yes to strings such as *bread* and no to strings such as *rencle*.

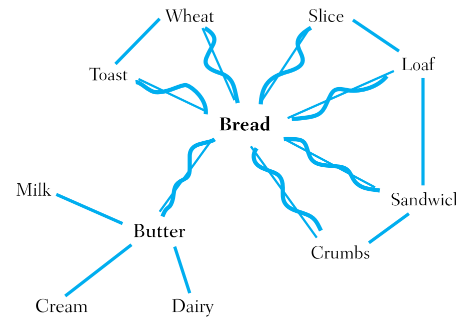
Meyer and Schvaneveldt (1971) discovered an interesting phenomenon. In their study, participants saw two words at a time, one above the other, and had to decide if both strings were words or not. If one of the strings was a real word (such as *bread*), participants were faster to respond if the other string was a semantically associated word (such as *butter*) than if it was an unrelated

FIGURE 7-2 ■ *Illustration of the Collins and Quillian (1969) experiment. Panel A shows the hypothesized underlying semantic network, and Panel B shows reaction times to verify sentences about information in the semantic network.*
SOURCE: Collins and Quillian (1969, p. 241).



word (such as *chair*) or a nonword (such as *rencle*). One interpretation of this finding invokes the concept of **spreading activation,** the idea that excitation spreads along the connections of nodes in a semantic network. Presumably, when the person read the word *bread,* he activated the corresponding node in

FIGURE 7-3 ■ *Depiction of spreading activation. Once the node for "bread" is excited, the activation travels to related nodes.*



semantic memory. This activity primed, or changed the activation level of, the nodes corresponding to words related to *bread.* Thus, when processing of the word *butter* began, the node corresponding to it was already excited, and processing was consequently faster. This priming effect, originally discovered by Meyer and Schvaneveldt, has been widely replicated in the years since (see Neely, 1990), and is a very important idea in understanding connectionist networks, to be described later.

You may note here a connection to the research on the word superiority effect described in Chapter 3. Recall that people are generally faster to recognize a particular letter (such as *D* or *K*) in the context of a word (such as *WOR_*) than they are to recognize it with no context or in the context of a nonword (such as *OWR_*). The explanations offered went roughly along the following lines: The word context helps letter recognition because a node corresponding to a word is activated in the former case. This automatic activation facilitates recognition of all parts of the word, thus facilitating letter recognition. The Meyer and Schvaneveldt (1971) results extend this idea a little more: Individual nodes can be activated not just directly, from external stimuli, but indirectly, through spreading activation from related nodes.

Soon after Collins and Quillian (1969) presented their model, others found evidence that contradicted the model's predictions. One line of evidence was related to the prediction of cognitive economy, the principle that properties and facts would be stored with the highest and most general node possible.

Carol Conrad (1972) found evidence to contradict this assumption. Participants in her sentence verification experiments were no slower to respond to sentences such as "A shark can move" than to "A fish can move" or "An animal can move." However, the principle of cognitive economy would predict that the property "can move" would be stored closest to the node for "animal" and thus that the three sentences would require decreasing amounts of time to verify. Conrad argued that the property "can move" is one frequently associated with "animal," "shark," and "fish" and that frequency of association rather than cognitive economy predicts reaction time.

A second prediction of Collins and Quillian's (1969) model had to do with hierarchical structure. Presumably, if the network represents such words (that in turn represent concepts) as *animals, mammals,* and *pigs,* then it should do so by storing the node for "mammal" under the node for "animal," and the node for "pig" under the node for "mammal." However, Rips, Shoben, and Smith (1973) showed that participants were faster to verify "A pig is an animal" than to verify "A pig is a mammal," thus demonstrating a violation of predicted hierarchical structure.

A third problem for the hierarchical network model was that it failed to explain why certain other findings kept appearing. One such finding is called a **typicality effect.** Rips et al. (1973) found that responses to sentences such as "A robin is a bird" were faster than responses to "A turkey is a bird," even though these sentences should have taken an equivalent amount of time to verify. In general, typical instances of a concept are responded to more quickly than atypical instances; robins are typical birds, and turkeys are not. The hierarchical network model did not predict typicality effects; instead, it predicted that all instances of a concept should be processed similarly.

These, among other problems, led to some reformulations as well as to other proposals regarding the structure of semantic memory. Some investigators abandoned the idea of networks altogether; others tried to extend and revise them. We'll consider each of these approaches in turn.

The Feature Comparison Model

Smith, Shoben, and Rips (1974) proposed one alternative to the hierarchical semantic network model, called a **feature comparison model of semantic memory.** The assumption behind this model is that the meaning of any word or concept consists of a set of elements called *features.* (We encountered the idea of features earlier, in Chapter 3, when we reviewed models of perception.) **Features** come in two types: **defining,** meaning that the feature must be present in every example of the concept, and **characteristic,** meaning the feature is usually, but not necessarily, present.

For instance, think about the concept "bachelor." The defining features here include "male," "unmarried," and "adult." It is not possible for a 2-year-old to be a bachelor (in our common use of the term), nor for a woman, nor for a married man. Features such as "is young" or "lives in own apartment" are also typically associated with bachelors, though not necessarily in the way that "male" and "unmarried" are—these are the characteristic features. Table 7-1 lists features for three concepts.

Table 7-1 Lists of Features for Three Concepts

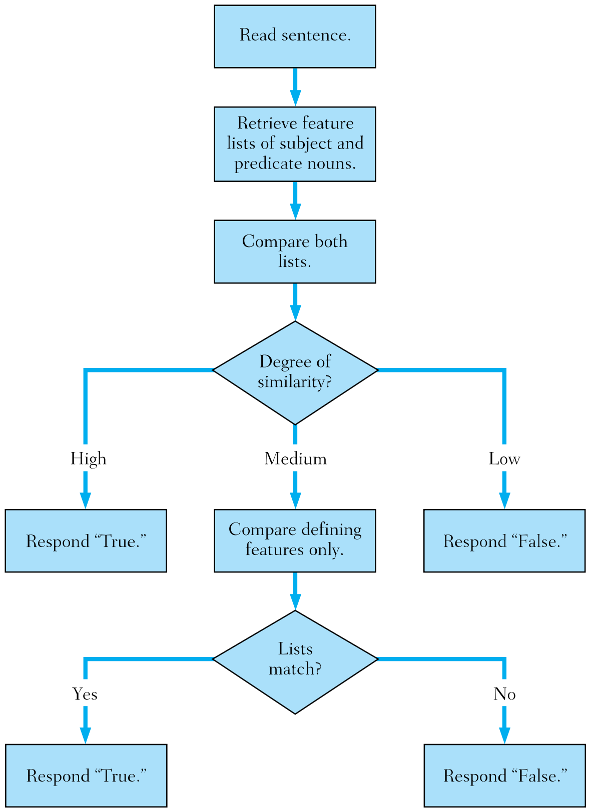
Bachelor	*Bernese Mountain Dog*	*Chair*
Male	Dog	Furniture
Adult	Black, white, and rust fur	Has a seat
Unmarried	Brown eyes	Has a back
Human	Large size	Has legs
	Bred for draft	

Assuming that semantic memory is organized in terms of feature lists, how is its knowledge retrieved and used? In particular, how can performance on a sentence verification task be explained? In the Smith et al. (1974) model, the verification of sentences such as "A robin is a bird" is again carried out in two stages, as in Figure 7-4. In the first stage, the feature lists (containing both the defining and the characteristic features) for the two terms are accessed, and a quick scan and comparison are performed. If the two lists show a great deal of overlap, the response "true" is made very quickly. If the overlap is very small, then the response "false" is made, also very quickly. If the degree of overlap in the two feature lists is neither extremely high nor extremely low, then a second stage of processing occurs. In this stage, a comparison is made between the sets of defining features only. If the lists match, the person responds "true"; if the lists do not match, the person responds "false."

The feature comparison model can explain many findings that the hierarchical network model could not. One finding it explains is the typicality effect: Sentences such as "A robin is a bird" are verified more quickly than sentences such as "A turkey is a bird" because robins, being more typical examples of birds, are thought to share more characteristic features with "bird" than do turkeys. The feature comparison model also explains fast rejections of false sentences, such as "A table is a fruit." In this case, the list of features for "table" and the list for "fruit" presumably share very few entries.

The feature comparison model also provides an explanation for a finding known as the *category size effect* (Landauer & Meyer, 1972). This term refers to the fact that if one term is a subcategory of another term, people will generally

FIGURE 7-4 ■ *Depiction of the Smith et al. (1974) feature comparison model.*
SOURCE: Smith et al. (1974, p. 22).



be faster to verify the sentence with the smaller category. That is, people are faster to verify the sentence "A collie is a dog" than to verify "A collie is an animal," because the set of dogs is part of the set of animals. The feature comparison model explains this effect as follows. It assumes that as categories grow larger (for example, from robin, to bird, to animal, to living thing), they also become more abstract. With increased abstractness, there are fewer defining

features. Thus in the first stage of processing there is less overlap between the feature list of a term and the feature list of an abstract category.

The model can also explain how "hedges" such as "A bat is sort of like a bird" are processed. Most of us know that even though bats fly and eat insects, they are really mammals. The feature comparison model explains that the processing of hedges consists of a comparison of the characteristic features but not the defining features. Because bats share some characteristic features with birds (namely, flying and eating insects), we agree they are "sort of like" birds. We recognize, however, that bats aren't really birds—presumably because they don't share the same defining features.

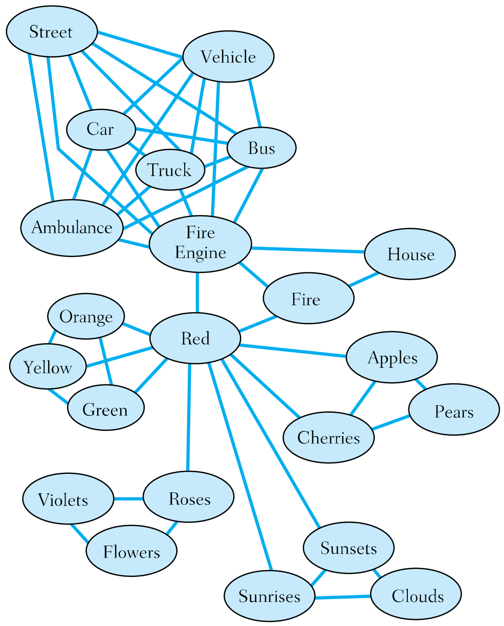
Despite the successes of the feature comparison model, evidence and arguments began to mount against its being taken as a complete model of how knowledge is represented. Among the most fundamental criticisms is one that rejects the very existence of defining features. Consider a concept such as "bird." Most people would initially agree that "has wings" is a defining feature. But suppose that through genetic or environmental accident a bird's wings are removed. Is it no longer a bird? Other arguments challenge the view that all, or even some, concepts have defining features (Rosch & Mervis, 1975). We will look at these assertions more carefully in Chapter 8 when we examine concepts in more detail.

Other Network Models

Collins and Loftus (1975) presented an elaboration of the Collins and Quillian (1969) hierarchical network model that they called *spreading activation theory.* In general, these authors sought both to clarify and to extend the assumptions made about the manner in which people process semantic information. They again conceived of semantic memory as a network, with nodes in the network corresponding to concepts. They also saw related concepts as connected by paths in the network. They further asserted that when one node is activated, the excitation of that node spreads down the paths or links to related nodes. They believed that as activation spreads outward, it decreases in strength, activating very related concepts a great deal but activating distantly related nodes only a little bit.

Figure 7-5 shows a representation of part of a semantic network, as Collins and Loftus (1975) conceived it. Notice that in this model, very similar concepts—such as "car" and "truck"—have many connecting links and are placed close to each other. Less similar concepts, such as "house" and "sunset" (both are red, at least sometimes), have no direct connections and are therefore spaced far apart. Each link or connection between two concepts is thought to have a certain weight or set of weights associated with it. The weights indicate how important one concept is to the meaning of a concept to which it is

FIGURE 7-5 ■ *Partial network representation of related concepts. Length of line segments indicates the degree of relatedness or connection between two concepts.*
SOURCE: Collins and Loftus (1975, p. 412).



connected. Weights may vary for different directions along these connections. Thus it may be very important to the meaning of *truck* that it is a type of vehicle, but not so very important to the meaning of *vehicle* that *truck* is an example.

Collins and Loftus (1975) described a number of other assumptions this model makes, together with explanations of how the model accounts for data from many other experiments. They dispensed with the assumptions of cognitive economy and hierarchical organization, helping their model avoid the problems of the Collins and Quillian (1969) model. However, many psychologists find the breadth of this model, which is its major strength, to be its major shortcoming as well, because it is difficult to make clear and strong predictions from the model regarding empirical findings. Thus, although the model is consistent with a number of findings, such as the typicality effect

and the category size effect, it is hard to think of data that would falsify the model. The proposal is therefore regarded more as a descriptive framework than as a specific model.

The ACT Models

Another network theory of memory has been developed and refined over several years by John Anderson (1976, 1983, 1993, 2005; Anderson, Budiu, & Reder, 2001). Called the **adaptive control of thought (ACT) model of memory,** it has evolved over the almost 30 years of its existence, and various versions (ACT-*, ACT-R) exist. Based on analogies to computers, ACT has given rise to several computer simulations of cognitive processing of different tasks. ACT models do not make the semantic/episodic distinction described earlier, but distinguish among three kinds of memory systems. The first is *working memory,* thought to contain information the system is currently using. The other two kinds are **declarative memory** and **procedural memory.**

Declarative memory contains knowledge, facts, information, ideas—basically, anything that can be recalled and described in words, pictures, or symbols. In contrast, procedural memory holds information concerning action and sequences of actions. Su, Merrill, and Peterson (2001) describe the distinction between the two somewhat differently, with declarative memory being explicitly represented and consciously accessible, whereas procedural memory is implicitly represented and thus perhaps not consciously accessible.

For example, when you ride a bicycle, swim, or swing a golf club, you are thought to be drawing on your procedural memory. Here's another example of procedural memory. Right now, almost all the telephones I use have touch-tone pads for dialing. I "know" many phone numbers only by the sequence of moves I make to enter the number on the keypad. If someone asks me for one of these phone numbers (a task that requires me to state information in words), I often find myself at a loss; then I start "dialing" on an imaginary keypad, watching where my finger goes and "reading off" the phone number based on the motions of my finger. You could say my knowledge of the phone number is procedural, not declarative. At least at first, I can't easily put that knowledge into words but can only perform it. Other examples of procedural memory might be your knowledge of how to tie a shoe, ride a bike, play a guitar chord, shift gears in a car. The distinction between declarative and procedural memory should help explain the intuition that your memory of who is currently president of the United States has a qualitatively different feel from your memory of how to execute a particular dance step.

Anderson (1983) believed that declarative memory stores information in networks that contain nodes. There are different types of nodes, including those corresponding to spatial images or to abstract propositions. As with other network models, ACT models allow both for activation of any node and for spreading activation to connected nodes. Anderson also posited the existence of a procedural memory. This memory store represents information in **production rules.** Production rules specify a *goal* to achieve, one or more *conditions* that must be true for the rule to apply, and one or more *actions* that result from applying the rule.

For example, a typical college student could use this production rule: "*If* the goal is to study actively and attentively (goal) *and* the noise level in the dormitory is high (condition) *and* the campus library is open (condition), *then* gather your study materials (action) *and* take them to the library (action) *and* work there (action)." Okay, that example was a bit contrived. But psychologists, computer scientists, and others have used production rules to build computer programs that simulate human problem solving. Box 7-1, from Anderson (1995), presents some examples of production rules for multicolumn subtraction.

Box 7-1 Production Rules for Multicolumn Subtraction

If the goal is to solve a subtraction problem,
Then make the subgoal to process the rightmost column.

If there is an answer in the current column
and there is a column to the left,
Then make the subgoal to process the column to the left.

If the goal is to process a column
and there is no bottom digit,
Then write the top digit as the answer.

If the goal is to process a column
and the top digit is not smaller than the bottom digit,
Then write the difference between the digits as the answer.

If the goal is to process a column
and the top digit is smaller than the bottom digit,
Then add 10 to the top digit
and set as a subgoal to borrow from the column to the left.

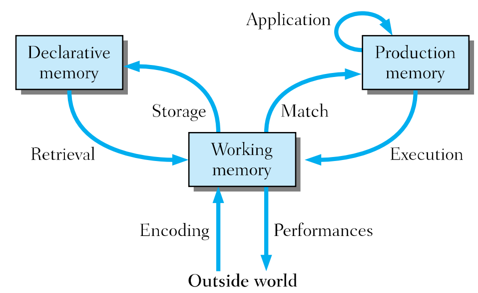
If the goal is to borrow from a column
and the top digit in that column is not zero,
Then decrement the digit by 1.

If the goal is to borrow from a column
and the top digit in that column is zero,
Then replace the zero by 9
and set as a subgoal to borrow from the column to the left.

SOURCE: Anderson (1995, p. 282).

Anderson's (1983) proposal was not meant merely to address the question of knowledge representation. Instead, his aim was to create a theory of *cognitive architecture,* a "theory of the basic principles of operation" built into human cognition. He proposed a system that included both memory storage and particular processing structures, as shown in Figure 7-6. Interestingly, this broad goal led him to develop proposals about knowledge representation that fit well with those of researchers whose aims were more focused.

FIGURE 7-6 ■ *The ACT* cognitive architecture. Adapted from Anderson (1983).*
SOURCE: Luger (1994, p. 323).



In the ACT models, working memory is actually that part of declarative memory that is very highly activated at any particular moment. The production rules also become activated when the nodes in the declarative memory that correspond to the conditions of the relevant production rules are activated. When production rules are executed, they can create new nodes within declarative memory. Thus ACT models have been described as very "activation-based" models of human cognition (Luger, 1994).

Connectionist Models

Earlier in the chapter I referred to the library metaphor, acting as if each piece of information stored in long-term memory existed as a particular item, stored in a particular location, much like a book in a library. This metaphor is a useful one within the information-processing framework, which assumes the existence of one or more distinct "stores" of memory.

Connectionist models make very different assumptions, and thus do not incorporate the library metaphor as easily. Let's take a brief look at connectionist models of memory to try to understand why. James McClelland, a pioneer of connectionist models of cognition, argues that connections models of memory

> [let] go of the idea that items are stored in memory as such. Instead the fundamental idea is that what is stored in memory is a set of changes in the instructions neurons send to each other, affecting what pattern of activity can be constructed from given inputs. When an event is experienced, on this view, it creates a pattern of activity over a set of processing units. This pattern of activity is considered to be the representation of the event. The formation of this pattern of activity provides the trigger for the creation of the instructions. The set of instructions is then stored in the connections among the units, where it is available for use in the construction of subsequent patterns of activity. Under some circumstances—for example, when the constructive process takes place in response to a recall cue—the cue may result in the construction of a pattern of activation that can be viewed as an attempted reconstruction of the pattern that represented the previously experienced event. Such a reconstructed representation corresponds to a recollection. The patterns themselves are not stored, and hence are not really "retrieved"; recall amounts not to retrieval but to reconstruction." (McClelland, 2000, p. 583)

Let's look at a concrete example, comparing network and connectionist models of semantic memory. Figure 7-7(A) presents a semantic network model of various concepts and should look rather familiar. Figure 7-7(B) presents a connectionist model of these same concepts. The concept *robin*, depicted in Figure 7-7(A) as a particular node with several related links to other nodes, is depicted in Figure 7-7(B) as a specific set of units being activated. A unit might correspond to an ability possessed by certain living creatures (e.g., fly) or to certain aspects such as color. Darkened units are activated units, and a connectionist network learns, over trials, that when the unit for "robin" becomes active, then other units should become active as well (for example, "can" and "grow," "move," and "fly," but not "swim").

How does this learning occur? Essentially, a connectionist network must be taught to develop patterns of activation through many trials with training examples. The procedure used, called "back propagation," is actually quite complicated, but I will offer a very simplified version here.

Initially, the connections between units (depicted in Figure 7-7(B) as the lines between the units) have weights that are all set at random and neutral values (such as 0.5, if the minimum and maximum values are 0 and 1). Activation weights result in the units they connect becoming active (or not). Training occurs by presenting a specific example (input pattern) to the network, which then generates a particular output. So, for example, at the beginning of training, the example "robin" might be activated, and the units for "can" and "pretty" and "fly" and "branches" might then become activated. This output is compared to target (correct) output, such as "can," "grow," "move," and "fly" all being activated, and no others. The network connections are then adjusted in this direction (they take on values closer to 1), all other connections are incrementally decreased (they take on values closer to 0), and the training process repeats, with new examples.

Typically, training takes place in a series of what connectionist researchers call "epochs," similar to trials of learning. Each epoch follows the procedure just described: An input pattern is presented, and an output pattern of activation is generated, then compared with a correct, target pattern of activation. Connection weights between units are adjusted accordingly, and another input pattern presented to start the next epoch. (For a more detailed and technical discussion of how this training procedure works, consult McClelland, 2000, or Chapter 4 of Clark, 2001; for a more recent example of a connectionist network designed to explore semantic memory, see McRae, 2004).

Let us pause and consider the different models of semantic memory we've just covered. We have seen several proposals for how knowledge is represented. The debate continues over the relative merits of network versus feature models to describe semantic memory. (For reviews, see Chang, 1986; Johnson & Hasher, 1987; Rumelhart & Norman, 1988.) Still, the discovery of semantic priming, the idea of spreading activation, and the experimental innovations designed to test models of semantic memory have all contributed to our understanding of the principles by which knowledge is stored and retrieved. The work reviewed here so far relates directly to another topic in cognitive psychology, the formation and use of concepts to classify information. We will examine this area in more detail in Chapter 8, when we look at other proposals for conceptual representation.

■ SCHEMATA

Network models are not the only way of depicting or representing knowledge in semantic memory. Other psychologists, dating back to Sir Frederick Bartlett (1932), invoke the concept of a schema, as we saw in Chapter 6. The term *schema* usually refers to something larger than an individual concept. Schemata (the plural of *schema*) incorporate both general knowledge about the world and information about particular events. Bartlett (1932) defined a schema as an "active organization of past reactions, or of past experiences, which must always be supposed to be operating in any well-adapted organic response" (p. 201). The key term here is *organization.* A **schema** is thought to be a large unit of organized information used for representing concepts, situations, events, and actions in memory (Rumelhart & Norman, 1988).

Rumelhart and Ortony (1977) viewed schemata as the fundamental building blocks of cognition, units of organized knowledge analogous to theories. Generally, they saw schemata as "packets of information" that contain both variables and a fixed part. Consider a schema for the concept *dog.* The fixed part would include the information that a dog is a mammal, has (typically) four legs, and is domesticated; the variables would be things like breed (poodle, cocker spaniel, Bernese mountain dog), size (toy, medium, extra large), color (white, brown, black, tricolored), temperament (friendly, aloof, vicious), and name (Spot, Rover, Tandy). Just and Carpenter (1987) compared a schema to a questionnaire with blanks that a person is supposed to fill in. Labels next to the blanks indicate what sort of information to fill in—for example, name, address, and date of birth.

Schemata can also indicate the relationships among the various pieces of information. For example, to end up with a dog, the "parts" of the dog (tail, legs, tongue, teeth) must be put together in a certain way. A creature with the four legs coming out of its head, its tail sticking out of its nose, and its tongue on the underside of its belly would not "count" as an instance of a dog, even if all the required dog parts were present.

Moreover, schemata can be connected to other schemata in a variety of ways. The schema for my dog, Tandy, for instance, is a part of a larger schema for dogs I have owned (Tandy, Bussey, Eskie, Flit, Tackle), which in turn is part of a larger schema of Bernese mountain dogs, which is part of a still larger schema of dogs, and so on. The schema for Bernese mountain dogs can also be connected with similar, related schemata, such as the one for Saint Bernard dogs (both breeds come from the canton of Bern, Switzerland) or the one for Rottweiler dogs (both classified as "working" breeds by the American Kennel Club and other registries).

Schemata also exist for things bigger than individual concepts. For example, consider meeting a new college roommate for the first time. Your knowledge of such an event can be said to be guided by a schema. Included in this schema would be the fixed part (the setting, a dormitory room; the characters, two students) and the variables (the opening conversation—"Hi. I'm Jane. Are you Susan?"; the sex of the students; the type of room; whether the students have previously talked or corresponded; whether parents are present).

Furthermore, schemata fill in *default values* for certain aspects of the situation, which let us make certain assumptions. For instance, student ages were not given. Lacking such specification, many readers would assume the two students were first-year students. This assumption would be the default value for the variable. Notice, however, that the default can be overridden simply by mentioning other values in the description of the situation.

Schemata are assumed to exist at all levels of abstraction; thus schemata can exist for small parts of knowledge (what letter does a particular configuration of ink form?) and for very large parts (what is the theory of relativity?). They are thought of as active processes rather than as passive units of knowledge. They are not simply called up from memory and passively processed. Instead, people are thought to be constantly assessing and evaluating the fit between their current situation and a number of relevant schemata and subschemata.

Some researchers think schemata are used in just about every aspect of cognition. Schemata are deemed to play an important role in perception and pattern matching as we try to identify the objects we see before us. They are considered important in memory functioning as we call to mind relevant information to help us interpret current information and make decisions about what to do next. We will see in Chapter 10 as well that schemata are thought to explain some aspects of text and discourse comprehension as we try to follow the meaning of a conversation, story, or textbook.

Scripts

One kind of schema, a schema for routine events, has been called a **script** (Schank & Abelson, 1977). Consider the best-known example of a script: going to a restaurant. Think for a moment (and even better, before reading further, make a few notes) about what happens when you go to a restaurant. Now do the same thing for these other events: attending a lecture, getting up in the morning, grocery shopping, and visiting a doctor. Schank and Abelson (1977) noticed that people's knowledge of what is involved in going to a restaurant was widely shared and was structured in very similar ways. They explained this similarity by saying that people share scripts.

Scripts are thought to be used in a variety of situations. For instance, if you go to a new restaurant, in a city you've never visited before, you can call on a script to tell you what to expect. In general, you should expect on entry to be greeted by a host or hostess, shown to a table when one is available, given menus, and so on. This knowledge cues you for how to behave appropriately. So if you enter a restaurant but don't see a host or hostess, it is normally a good idea to wait (at least a little while) before sitting down; your script tells you this.

Scripts also let us make a number of inferences (Rumelhart & Norman, 1988). Consider this story: "Tim really wanted a chicken-fried steak. So he went to a restaurant and ordered it. Finally, he asked for the check, paid it, and left." Other, apparently omitted information can be inferred by use of the script. For instance, we can infer that Tim entered the restaurant and was seated, that someone took and delivered his order, that someone cooked his steak, that he had money before entering the restaurant, and so on. The story didn't need to say all this, because it gave enough information for us to call up the appropriate script ("going to a restaurant"), and that script filled in the rest.

Bower, Black, and Turner (1979) showed that if information from a story was presented in scrambled order, people tended to recall it in the scripted order. In a further experiment, the investigators presented stories that mentioned only some of the events in a typical script. They found that in a later recall task, participants often "recalled" information that wasn't in the story but was in the relevant script.

The preceding finding was replicated in a study by Owens, Bower, and Black (1979). They presented participants with stories about a character's doing such routine things as making coffee, visiting a doctor, and going to a lecture. Participants in the experimental condition read a three-line description of a problem, such as "Nancy woke up feeling sick again, and she wondered if she really was pregnant. How would she tell the professor she had been seeing? And the money was another problem." Participants were later asked to recall the stories as close to verbatim as possible. Participants who read the problem description recalled more of the story episodes than control participants but also "recalled" more than was in the stories. These intrusions appeared to come from the underlying scripts (e.g., of a young pregnant woman) and became more frequent with longer retention intervals.

The authors suggested that although scripts play an important role in helping us organize recall, they force us to pay a price: other, script-related information intruding into our memory. Thus part of the reason Bartlett's participants produced such distorted recalls of "The War of the Ghosts" (discussed in Chapter 6) is that they used their schemata and scripts for stories and "regularized" the original folktale, making it conform more to their own cultural expectations of how a story should proceed.

■ IMPLICIT VERSUS EXPLICIT MEMORY

We have already seen that some psychologists favor making a distinction between two types of memory: episodic and semantic. Some psychologists also distinguish between declarative and procedural memories. Many argue these kinds of memory form different systems; that is, they operate on different principles, store different kinds of information, and so on. Others disagree, declaring there is no compelling reason to believe that more than one *type* of memory exists.

Other cognitive psychologists have proposed another distinction between kinds of memory: implicit and explicit (Roediger, 1990; Schacter, 1987). **Explicit memories** are things that are consciously recollected. For example, in recalling your last vacation, you explicitly refer to a specific time (say, last summer) and a specific event or series of events. Your recall is something you are aware of and may even be something deliberate. **Implicit memory,** by contrast, is memory that is not deliberate or conscious but shows evidence of prior learning and storage. Schacter (1996) poetically described implicit memory as "a subterranean world of nonconscious memory and perception, normally concealed from the conscious mind" (pp. 164–165).

Laboratory work on implicit memory has been mainly concerned with a phenomenon known as *repetition priming.* We've already reviewed the phenomenon of **semantic priming,** in which exposure to one word (for example, *nurse*) facilitates the recognition or other cognitive processing of a semantically related word (for example, *doctor*). **Repetition priming** is priming of a somewhat different sort: facilitation of the cognitive processing of information after a recent exposure to that same information (Schacter, 1987, p. 506). For example, participants might be given a very brief exposure (of 30 milliseconds or less) to a word (such as *button*) and soon afterward be given a new word completion task (for example, "Fill in the blanks to create the English word that comes to mind: _U _T O_"). This task is called a *word stem completion* task. The repetition priming effect is demonstrated by an increased probability of responding "button" to the stimulus given in the word completion task, relative to the performance of participants not shown the word *button.* (Note that there are other possible ways to complete the word, such as *mutton* or *suitor.*)

Research on repetition priming has yielded several findings relevant to the topic of knowledge representation. The first is that nonwords typically show no or little repetition priming relative to real words. Thus exposing a participant to a stimulus such as *daxton* will probably not prime the participant to recognize or remember it later. Presumably, this is because *daxton* is not a word and therefore has no associated node in semantic memory that can be activated. A second finding is that priming is greater for words that share the same morphology, or roots of meaning, than for words that are visually or aurally similar. Thus a stimulus such as *sees* can prime responses to *seen* (a word that shares meaning with *sees*) but not to *seed* (a visually similar stimulus) or *seize* (a similar-sounding stimulus).

Do laboratory demonstrations of implicit memory have any real-world relevance? Investigators who study implicit memory believe so. One real-world example of implicit memory was reported by Sergei Korsakoff, who in 1889 described patients with amnesic symptoms that have come to be known as *Korsakoff's syndrome.* One patient to whom he had administered an electric shock professed not to remember the shock but, on seeing the case containing the shock generator, told Korsakoff that he feared Korsakoff had probably come to electrocute him (Schacter, 1987, pp. 503–504).

Other work with amnesic patients demonstrated findings to support the idea of a dissociation between implicit and explicit memory. For example, Warrington and Weiskrantz (1970) conducted a more controlled investigation: They presented a variety of memory tasks to four amnesic patients, as well as

to eight patients without brain damage who served as a control group. In one experiment (Experiment 2), participants received two "explicit memory" tasks (the quotation marks indicate the authors did not use this term to describe them), a free-recall task and a recognition task, similar to those described in Chapter 5.

Participants also worked on two "implicit memory" tasks. One was a word completion task, similar to the one just described. The other presented participants with words in which the letters were visually degraded; they were asked to guess the word being displayed. All four tasks involved a prior presentation of various words. In the two "explicit" tasks, participants were asked to recall consciously or recognize the words previously presented. In the two "implicit" tasks, participants were *not* reminded of the prior presentation of words but merely asked to guess the word being presented (that is, in degraded letters or partially, by a word stem).

Figure 7-8 presents the results. It shows quite clearly that amnesic participants performed more poorly than nonamnesic participants on the explicit memory tasks but quite comparably to nonamnesic participants on the implicit memory tasks. In other words, their amnesia seemed to selectively hurt performance on explicit memory tasks. These results have been replicated several times and on a variety of tasks (Shimura, 1986).

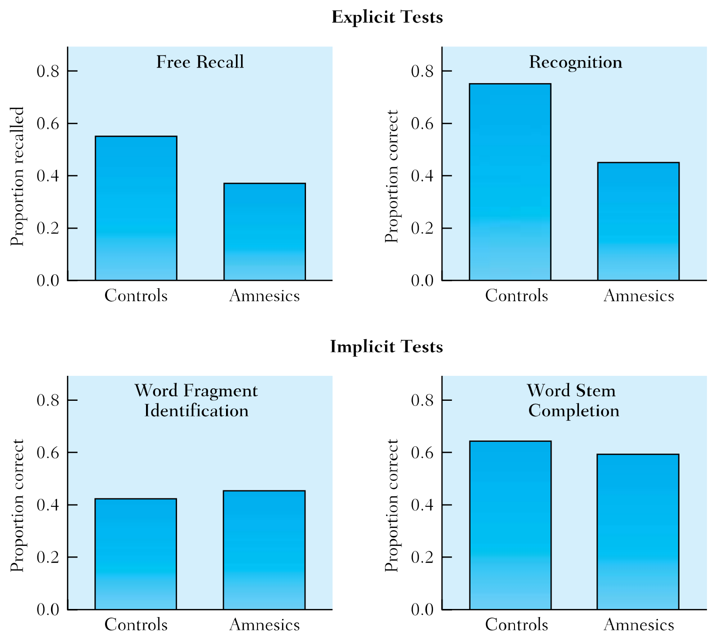
Phenomena such as the one depicted in Figure 7-8 are sometimes called "dissociative," because performance on one task appears independent of (or dissociated from) performance on another. Dissociative phenomena do not by any means occur only with amnesic participants. Many studies (reviewed by Roediger, 1990) have demonstrated striking differences in performance on implicit and explicit memory tasks with normal participants. Schacter (1996) reported that repetition priming effects could persist as long as an entire week, even when his experimental participants denied that the primed words had been previously seen in the laboratory!

How are such dissociation phenomena best explained? Roediger (1990) presented two distinct possibilities. One is to postulate two memory *systems,* such as declarative and procedural memory, and to assert that explicit memory tasks rely on the former and implicit memory tasks rely on the latter. Schacter (1996) even speculated that different brain structures are associated with the two different memory systems. The dissociation in performance on the two tasks would then be assumed to reflect that two memory systems operating in different ways are at work.

The second possibility is that the two kinds of memory tasks require different cognitive procedures, although they both tap into a common memory system (Roediger, 1990). One idea consistent with this proposal is that most implicit memory tasks require *perceptual* processing (that is, interpreting sensory information in a meaningful way) and that explicit memory tasks require *conceptual*

FIGURE 7-8 ■ *Results from the Warrington and Weiskrantz (1970) study; figure created by Roediger (1990).*

SOURCE: Warrington and Weiskrantz (1970, p. 630).



processing (in other words, drawing on information in memory and the knowledge base). In this view, the type of processing required in the two types of tasks explains dissociation phenomena. Much debate focuses on the question of whether the two approaches can be reconciled (Schacter, 1989; Whittlesea & Price, 2001). Essentially, this debate hinges on whether there are multiple and distinct systems of memory, each operating on different principles, or a single memory system that supports different kinds of processing.

The Process Dissociation Framework

Jacoby and his colleagues (Hay & Jacoby, 1996; Jacoby, 1991, 1998; Toth, Lindsay, & Jacoby, 1992; Toth, Reingold, & Jacoby, 1994) took issue with the

idea that implicit memory and explicit memory represent two distinct memory systems and argued for what he called the **process dissociation framework.**

Jacoby asserted that the fact that people perform differently on implicit memory tasks from the way they do on other memory tasks does not point to the existence of an implicit memory. His claim rested on the idea that implicit memory tasks of the sort used by Schacter, Warrington and Weiskrantz, and others are not necessarily *pure* measures of any memory system. Any task relies on a combination of abilities; rarely, if ever, can any test be constructed that measures *only* the aspect it is intended to measure. As an example, consider the last midterm exam you took. Although this test was, I hope, a valid and reliable test of the subject matter (calculus, history, music, or whatever), the test also reflected some of your other abilities (for example, to read, to recall relevant information).

Jacoby (1991) preferred to think about memory tasks as calling on two different processes: intentional and automatic ones. The parallel here with the topic of attentional versus controlled processing reviewed in Chapter 4 is very much by design:

> Performance on direct [that is, explicit] tests of memory typically requires that people intentionally recollect a past episode, whereas facilitation on indirect [implicit] tests of memory is not necessarily accompanied by either intention to remember or awareness of doing so. This difference between the two types of test can be described in terms of the contrast between consciously controlled and automatic processing. (pp. 515–516)

Jacoby (1991) argued that some memory tasks, such as one in which you try to recall a specific incident or fact, involve a great deal of conscious intention. Other tasks, such as judgments of familiarity (for example, the kind of task where you are asked if you've ever seen or heard a stimulus before), involve much more automatic processing. However, each task could draw on both intentional and automatic processing. As you try to recall a specific formula for a test, for instance, you might write down what you think it is, then see if what you've written looks familiar. Conversely, if you are a participant in an implicit memory experiment who is asked to fill in the blanks to make a word out of __ *Z* __ *L E*__, you actually might briefly recall having seen the word *azalea* just a day ago in the same laboratory.

Jacoby (1991) adopted a procedure similar in structure to those used in some of the attentional work we examined in Chapter 4. He tried to set up tasks in which automatic memory processes would either facilitate or hinder performance on an intentional memory task. Automatic processes are commonly described as arising when one is distracted or inattentive; controlled processes occur when one is focused, alert, and intentional about performing a particular task.

Some of Jacoby's best-known work comes from what have been called his "false fame" experiments (Jacoby, Woloshyn, & Kelley, 1989). Participants are shown a list of names of people, none of whom were famous (for example, Sebastian Weisdorf). Some participants are asked to study this list with full attention; others, in a divided-attention task. Later, all participants are given a new list of names, which includes names of famous people, names from the previously studied list (which they are told consisted only of nonfamous people), and names never before seen that were nonfamous, and they are asked to judge the fame of each name on this new list.

Participants in the divided-attention condition were more likely to falsely attribute fame to those names that had been previously studied. Jacoby et al. (1989) interpreted this as evidence for an automatic memory process. Their reasoning was as follows: Participants in the full-attention condition knew that names from the studied list were nonfamous and, moreover, had better recollection of just what names had been studied. Therefore, they consciously used that information in judging those names as being nonfamous. Participants in the divided-attention condition did not learn the list of names as well; when encountering the second list, they did not have as clear memories for whether a particular name was on the studied list. They instead used their familiarity with the name (which resulted from an automatic memory process only) as a basis for judging fame. Unfortunately, exposure to the names on the study list increased the familiarity of those names too, and later these were falsely judged to be famous.

Marcia Johnson and her colleagues (Johnson, Nolde, & De Leonardis, 1996) have come to similar conclusions in their work on **source-monitoring errors.** Briefly, these researchers are interested in people's inability to remember the original *source* of their memories—where they originally obtained the information. For example, imagine you attend a lecture on Sigmund Freud, in which the lecturer gives some biographical information. Later that week, you watch a PBS special about the father of psychoanalysis, which presents similar, but not identical, biographical information. You could later come to believe that the source of your information, say, that Freud was born in 1856, came from the lecturer, when it really was presented in the television program.

Johnson calls this inability a source-monitoring failure and regards it as a very important cause of memory errors. Johnson's explanation for source-monitoring failures goes something like this: When information in long-term memory is activated, it is nonetheless incomplete or ambiguous or both. When we try to determine whether something is a bona fide memory or simply a story we've heard, we may judge this simply on the basis of general familiarity. But, as Jacoby has suggested, using familiarity as a basis for judgment is not a foolproof evaluation metric, and sometimes it leads to error.

We can expect much research in this area in the coming years. Questions such as "What is the nature of the mental representation?" "Which inferences are easy to make using general knowledge, and which inferences are harder?" and "How does knowledge representation change as a function of practice and expertise?" must all be answered. Knowledge representation and organization are critically important to cognitive psychologists. For one thing, the issue of how knowledge is mentally represented underlies the important question "What is common sense?" Workers in artificial intelligence are discovering over and over again that a truly intelligent program or system must have a wide and deep knowledge base and must be able to store and retrieve a great deal of information about the world. The knowledge base must be organized efficiently. So far, the only creatures who have demonstrated efficient organization of such vast knowledge bases are human beings. The challenge now is to find out just how we accomplish this marvelous feat.

Summary

1. There are a number of different theoretical frameworks and empirical tests of the ways in which information in permanent memory is stored and organized. Three distinct proposals for dividing memory into systems function quite differently, as follows.
2. Tulving's proposal divorces *episodic memory* from *semantic memory,* seeing the latter as a storage of permanent knowledge. In this framework, knowledge is deemed to consist of a number of interrelated ideas, each comprising, typically, smaller units that correspond to the basic "packets" of meaning. The various models—hierarchical networks, feature lists, propositional networks, schemata, scripts—differ on the exact structure of the mental representation but generally agree that the "basic" unit of information represented is at the level of the individual word or concept. Connectionist models, in contrast, deny that concepts are represented as individual units, but rather, suggests they are represented as patterns of activation across different units.
3. A second proposal for separate memory systems distinguishes between *declarative* (knowing that *X* . . .) and *procedural* (knowing how to do *X*) memory. In this proposal, general knowledge is stored in declarative memory. Theorists often assert that declarative memory is organized as something analogous to a propositional network.
4. A third proposed division of memory distinguishes between *explicit* and *implicit* memory: The former refers to conscious recollections; the latter, to facilitation in performance as a function of past learning without awareness of that past learning. In this proposal, implicit memory phenomena have been seen as ways of determining how general knowledge is organized.

5. How well these three proposals fit together is a matter of some debate. For instance, semantic memory can be mapped onto declarative memory. One might propose that explicit memory relies on this declarative/semantic base. Procedural memory might be involved in implicit memory phenomena. Alternatively, one could argue that episodic memory is the basis for explicit memory of autobiographical events and that semantic memory is involved in many implicit memory tasks. It is also possible to reject the proposals for distinct memory systems.
6. Some have argued against associating different memory *tasks* with different memory systems. Jacoby (1991) believed the best way of understanding memory processes is to distinguish between automatic and intentional memory processes.
7. Clearly, despite the existence of a number of complex, logically crafted models of knowledge representation and organization, we are a long way from a satisfying account of how these processes work.

Review Questions

1. Describe the semantic/episodic memory distinction, and discuss the reasons why some psychologists make the distinction and others don't.
2. Contrast the hierarchical semantic network model of semantic memory (Collins & Quillian) with the feature comparison model (Rips, Shoben, & Smith), noting which experimental findings each explains and which findings each is less able to explain.
3. Explain the concept of spreading activation, and review the evidence that leads some psychologists to maintain that it is a property of semantic memory.
4. The research on knowledge representation typically involves laboratory research with people working on somewhat artificial tasks (for example, lexical decision, sentence verification). Does such research have much bearing on cognition in real life? Defend your answer, and use specific examples to illustrate your points.
5. What are schemata and scripts? How might they account for memory for autobiographical events, such as those discussed in Chapter 6?
6. Describe how evidence from neuropsychological studies can be used to illuminate debates over the existence of different memory systems. What are some possible limitations of these studies?
7. Describe the distinction between declarative and procedural memory and that between implicit and explicit memory. Do these two distinctions fit together well? How or how not?

Key Terms

adaptive control of thought (ACT) model of memory
characteristic feature
cognitive economy
declarative memory
defining feature
episodic memory
explicit memory
feature comparison model of semantic memory
hierarchical semantic network model of semantic memory
implicit memory
lexical decision task
lexicon
memory systems
procedural memory
process dissociation framework
production rules
repetition priming
schema
script
semantic memory
semantic network
semantic priming
source-monitoring error
spreading activation
typicality effect

CogLab Demonstrations

To check your knowledge of the key concepts in this chapter, take the chapter quiz at http://www.thomsonedu.com/psychology/galotti. Also explore the hot links that provide more information.

The **Lexical Decision** task is presented in the CogLab demonstration by the same name.

Web Resources

Visit our website. Go to http://www.thomsonedu.com/psychology/galotti, where you will find online resources directly linked to your book, including quizzes, flashcards, crossword puzzles, and glossaries.

CHAPTER

8

Concepts and Categorization

Theoretical Descriptions of the Nature of Concepts
- The Classical View
- The Prototype View
- The Exemplar View
- The Schemata View
- The Knowledge-Based View

Forming New Concepts and Classifying New Instances
- Concept Attainment Strategies
- Acquiring Prototypes
- Implicit Concept Learning
- Using and Forming Scripts
- Psychological Essentialism

If your college or university is like the one where I teach, you probably have to fulfill certain graduation requirements—among them, distribution requirements, which mandate your taking a certain number of courses in each of several groups. For example, Carleton College has four distribution groups: arts and literature (including most courses in studio art, art history, English, literature in translation, literature in foreign languages, and music), social sciences (including educational studies, economics, political science, psychology, and sociology/anthropology), natural science and mathematics (including astronomy, biology, computer science, chemistry, geology, mathematics, and physics), and humanities (including history, philosophy, and religion). The groupings of subject matter into larger distribution groups illustrates my college's categorization, or assignment of courses to groupings.

Of course, not all colleges have the same groups or the same assignment of courses to groups. For example, at other schools my home discipline, psychology, is

often assigned to the natural sciences division. At many schools, arts and humanities are grouped together. I'm not entirely sure how the Carleton grouping came to be, but I am sure the dean or committee that created it had a mental representation of this category, something that a cognitive psychologist would call a *concept*.

We have encountered the idea of mental representations several times before. We have seen that many cognitive psychologists (particularly those within the information-processing paradigm) believe that such representations guide cognitive processing and behavior. How you regard something may often be influenced by what type of thing you believe it to be. For example, you would probably react and behave one way if told that a severe thunderstorm was taking place outside, and another way if you were told it was a hurricane. Your classification of storms into two categories suggests that you see distinctions between them. Presumably, such distinctions cause your reactions to storms to depend on classification.

A related, real-life example comes from medical diagnosis. Suppose you wake up one day feeling achy, lethargic, congested, and feverish. Your symptoms could indicate nothing more serious than flu. Or your symptoms could be the harbinger of a much more serious illness. It is your doctor's job to make the diagnosis, which essentially is to assign your pattern of symptoms to a category corresponding to known diseases or medical problems. The categorization allows the physician to determine appropriate treatment and predict the time course of recovery. To make the diagnosis, your physician must have an idea of the various categories (possible medical problems) to be considered. Indeed, physicians are not the only ones who categorize illnesses, as shown by a recent study of laypeople's categorization of forms of mental illness (Kim & Ahn, 2002).

In this chapter, we'll look at concepts and how they are formed. We'll examine different theoretical descriptions of how concepts are structured and their implications for how we assume our mental representations work. We'll then focus on how concepts are accessed and used in categorizing new objects, patterns, or events. Many ideas discussed in the early part of the chapter will extend and elaborate on proposals presented in Chapter 3, "Perceiving Objects and Recognizing Patterns" (pattern recognition and classification have many similarities, as we shall see), and in Chapter 7, "Memory for General Knowledge." Similarly, our examination of categorization will anticipate some later discussions about language, thinking, reasoning, and decision making (Chapters 10–13). You can probably already see that an understanding of how people form and use concepts is relevant to several other cognitive processes and abilities. Medin (1989) has in fact argued that "concepts and categories serve as building blocks for human thought and behavior" (p. 1469). Lamberts and Shanks (1997) have argued that the issue of how things such as concepts are mentally represented is a central concern of cognitive psychology.

What are concepts and categories, and how do they differ? The distinction turns out to be a little blurry but can still be made. Medin (1989) defined a concept as "an idea that includes all that is characteristically associated with it" (p. 1469). In other words, a **concept** is a mental representation of some object, event, or pattern that has stored in it much of the knowledge typically thought relevant to that object, event, or pattern. Most people's concept of "dog," for example, would include information to the effect that a dog is an animal, has four legs and a tail, has a reputation as "man's best friend," is a common pet, and so on.

A **category** can be defined as a class of similar things (objects or entities) that share one of two things: either an essential core (example: why all science courses are considered "science") or some similarity in perceptual, biological, or functional properties (Lin & Murphy, 2001). When a psychologist thinks about categories, she usually thinks about several different ones, into which various things get sorted. In the game 20 Questions, a common opener is, "Is it an animal, vegetable, or mineral?" This question seeks to categorize, or sort, the to-be-guessed item into one of three things. Sometimes categories are described as existing objectively in the world, and concepts are described as mental representations of categories (Medin, 1989).

Concepts help us establish order in our knowledge base (Medin & Smith, 1984). Concepts also allow us to categorize, giving us mental "buckets" in which to sort the things we encounter, letting us treat new, never-before-encountered things in the same way we treat familiar things that we perceive to be in the same set (Neisser, 1987). Categorization also allows us to make predictions and act accordingly. If I see a four-legged creature with a tail coming toward me, my classification of it as either a dog or a wolf has implications for whether I'll want to call to it, run away, pet it, or call for help. Smith and Medin (1981) elaborated on the important role concepts play in our mental life:

> Without concepts, mental life would be chaotic. If we perceived each entity as unique, we would be overwhelmed by the sheer diversity of what we experience and unable to remember more than a minute fraction of what we encounter. And if each individual entity needed a distinct name, our language would be staggeringly complex and communication virtually impossible. Fortunately, though, we do not perceive, remember, and talk about each object and event as unique, but rather as an instance of a class or concept that we already know something about. (p. 1)

We will first examine different theoretical accounts about the nature and structure of concepts. Next, we'll look at how concepts are formed or acquired. Finally, we'll examine how people actually use concepts through the process of categorization. Throughout this chapter, we'll be focusing on concepts of objects and nouns, because they are the most commonly studied at present in

cognitive psychology. We will see, however, that the kind of concept studied may affect the concept theories that are subsequently created. So it will be useful to keep in mind that psychologists have yet to explore fully the entire range of people's concepts.

THEORETICAL DESCRIPTIONS OF THE NATURE OF CONCEPTS

In Chapter 7, we reviewed proposals for how our knowledge bases are represented and organized. Models of semantic memory describe the ways in which representations of different concepts are interrelated. Here we will concentrate on the representation and organization of individual concepts. We will explore five distinct proposals on how concepts are represented and structured. Each one provides a different answer to the question "What information do we have when we have a particular concept?" Each proposal will therefore have different implications for the question of how concepts are formed, acquired, or learned.

The Classical View

The classical view of concepts was the dominant view in psychology up until the 1970s and dates back to Aristotle (Smith & Medin, 1981). This proposal is organized around the belief that all examples or instances of a concept share fundamental characteristics, or **features** (Medin, 1989). In particular, the **classical view of concepts** holds that the features represented are individually necessary and collectively sufficient (Medin, 1989). To say a feature is individually necessary is to say that each example must have the feature if it is to be regarded as a member of the concept. For example, "has three sides" is a necessary feature of the concept *triangle;* things that do not have three sides are automatically disqualified from being triangles. To say that a set of features is collectively sufficient is to say that anything with each feature in the set is automatically an instance of the concept. For example, the set of features "has three sides" and "closed, geometric figure" is sufficient to specify a triangle; anything that has both is a triangle. Table 8-1 presents some other examples of sets of features or of concepts that are individually necessary and collectively sufficient.

The classical view of concepts has several implications. First, it assumes that concepts mentally represent lists of features. That is, concepts are not representations of specific examples but rather abstractions containing information about properties and characteristics that all examples must have. Second, it assumes that membership in a category is clear-cut: Either something

Table 8-1 Examples of Concepts and Their Features

	Bachelor	*Triangle*	*Uncle*	*Prime Number*
Concept	Male	Geometric figure	Male	Integer divisible by two numbers: itself and 1
Features	Adult Unmarried Human	Three-sided Planar	Sibling One or more siblings has a child	

has all the necessary and sufficient features (in which case it is a member of the category), or it lacks one or more of the features (in which case it is not a member). Third, it implies that all members within a category are created equal: There is no such thing as a "better" or "worse" triangle.

Work by Eleanor Rosch and colleagues (Rosch, 1973; Rosch & Mervis, 1975) confronted and severely weakened the attraction of the classical view. Rosch found that people judged different members of a category as varying in "goodness." For instance, most people in North America consider a robin and a sparrow very good examples of a bird but find other examples, such as chickens, penguins, and ostriches, not as good. Notice the problem this result presents for the classical view of concepts. The classical view holds that membership in a category is all-or-none: Either an instance (such as robin or ostrich) belongs to a category, or it doesn't. This view has no way to explain people's intuitions that some birds are "birdier" than others.

People's judgments of typicality, the "goodness" of the instance in the category, was later shown to predict several aspects of their performance on different tasks. For example, participants in a sentence verification task were faster to respond (true or false) to a sentence such as "A robin is a bird" than to a sentence such as "A chicken is a bird" (McCloskey & Glucksberg, 1978; Rosch, 1973; Smith et al., 1974). Asked to list instances of a concept, people were more likely to list typical than atypical instances (Mervis, Catlin, & Rosch, 1976). In semantic priming studies (see Chapter 7 for a review), highly typical instances often led to better priming (Rosch & Mervis, 1975; Rosch, Simpson, & Miller, 1976).

All these results are not easily explained within a classical framework. In addition, other studies cast doubt on the idea that people typically store and refer to a list of necessary features when judging category membership. McCloskey and Glucksberg (1978) gave participants a list of items and asked them to judge whether the items belonged to certain categories (for example,

"Does 'chair' belong to the category 'furniture'?"). The classical view would predict very strong agreement across people, but McCloskey and Glucksberg's participants in fact disagreed considerably on atypical instances (for example, "Do 'bookends' belong to the category 'furniture'?"). Participants were often inconsistent in their own responses in different sessions. This result argued especially strongly against the classical assumption that categories have clearly defined boundaries. Finally, even when given specific instructions to do so, most people cannot generate lists of features that are individually necessary and collectively sufficient to specify membership in a category (Ashcraft, 1978; Rosch & Mervis, 1975).

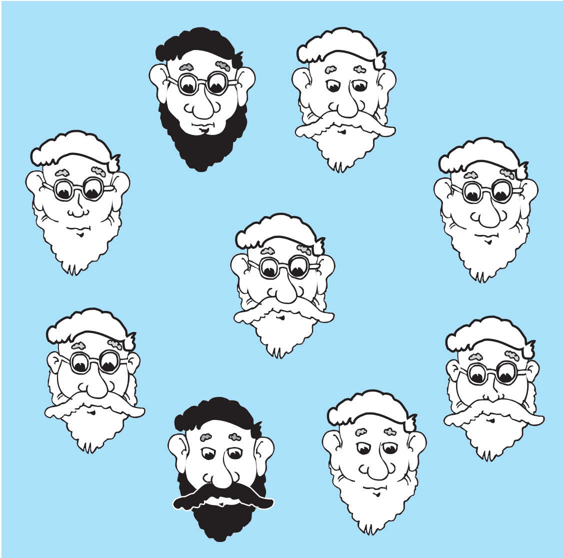
The Prototype View

A second theoretical view of the nature of concepts, known as the *prototype view,* was proposed in the 1970s. The **prototype view of concepts** denies the existence of necessary-and-sufficient feature lists (except for a limited number of concepts such as mathematical ones), instead regarding concepts as a different sort of abstraction (Medin & Smith, 1984). Like perceptual researchers (see Chapter 3), conceptual researchers believe in the existence of mental **prototypes,** idealized representations of some class of objects or events. Specifically, researchers studying the prototype view of concepts hold that prototypes of concepts include features or aspects that are *characteristic*—that is, typical—of members of the category rather than necessary and sufficient. No individual feature or aspect (except very trivial ones, such as "is an object") need be present in the instance for it to count as a member of the category, but the more characteristic features or aspects an instance has, the more likely it is to be regarded as a member of the category.

The prototype view of concepts and categories often refers to the **family resemblance structure of concepts** (Wittgenstein, 1953), a structure in which each member has a number of features, sharing different features with different members. Few, if any, features are shared by every single member of the category; however, the more features a member possesses, the more typical it is. Figure 8-1 provides an example of family resemblance. Note that the Smith brothers (modeled after the men on Smith Bros. Cough Drop boxes) have several shared features: light hair, bushy mustache, large ears, and eyeglasses. Not every Smith brother has every feature, but the brother in the middle, having them all, would likely be judged by Smith friends to be the most typical Smith of the bunch. Note that he shares big ears, eyeglasses, and light hair with the brother in the "ten o'clock" position and a mustache and big ears with the "seven o'clock" brother. Indeed, different pairs of brothers share different features.

The prototype view of concepts explains typicality effects by reference to family resemblance. The idea is that the more characteristic features an instance

FIGURE 8-1 ■ *An example of family resemblance.*
SOURCE: Armstrong et al. (1983, p. 269).



of a concept has, the stronger the family resemblance between that instance and other instances, and therefore the more typical an instance it is. Presumably, then, a robin is thought of as a more typical bird than a penguin because the robin possesses more characteristic bird features, such as "is small," "flies," "eats worms," and "lives in a tree." Even with well-defined concepts such as *bachelor,* some examples seem more bachelorlike than others.

For example, is my 13-year-old son Tim a good example of a bachelor? He is male and unmarried. And probably, he's a better example of a bachelor today than he was 10 years ago. What about the pope? The point here is that both people may meet the technical definition of a bachelor (there's some disagreement over whether the definition includes "adult"), but neither is as good an example as might be someone such as the current male teenage heartthrob.

In one set of studies, Rosch and Mervis (1975) presented their undergraduate participants with terms (such as *chair, car, orange, shirt, gun, peas*) from six different superordinate categories (such as "furniture," "vehicle," "fruit," "clothing," "weapon," "vegetable") and asked them to list attributes "common to and

characteristic of" those objects. So, for example, for the word *chair* a participant might list "has four legs; used to sit in; sometimes has arms; used in homes and offices." Then Rosch and Mervis tallied a list of all the attributes any participant listed for all basic-level terms belonging to a superordinate category (for example, all the attributes listed for *chair, sofa, table, dresser, desk, bed, clock, closet, vase, telephone*). Next, they computed, for each item, the number of attributes commonly listed for it. They found that items such as chair and sofa—ones that seem more prototypical of the superordinate category "furniture" —had many more of the "furniture" attributes listed than did items such as clock or telephone, which are both not at all prototypical examples of furniture. However, very few (0 or 1) attributes in any of the six superordinate categories were true of all 20 items for the category (for example, attributes true of all fruits).

A prototype, then, is some sort of abstraction that includes all the characteristic features of a category. The prototype may or may not be an actual instance of the category. Prototypes are often thought of as mental "summaries" or "averages" of all the instances, although there are some problems with this view (Barsalou, 1985). The general idea of the prototype view, then, is that concepts have one or more "core" representations, based on a family resemblance structure, but have no rigid boundaries.

Rosch and her colleagues (Rosch, Mervis, Gray, Johnson, & Boyes-Braem, 1976) made another important discovery about concepts. Although concepts exist at many different levels of a hierarchy (for example, "Bernese mountain dog," "dog," "canine," "mammal," "animal"), one level of abstraction appears psychologically fundamental. They called this the "basic" level and distinguished it from both higher-level (superordinate) and lower-level (subordinate) concepts.

To understand the distinctions between the **basic level of categorization** and other levels, consider the purpose of categorization. On the one hand, we want to group together similar objects, events, people, ideas, and so on. On the other hand, we want our categorization to distinguish among objects, events, people, and ideas that differ in important ways. There must be some compromise between these two goals. Rosch and colleagues consider the basic level to be the best compromise.

"Piano" and "guitar" are examples of two basic-level categories. Such categories include members that are maximally similar to one another, unlike **superordinate levels of categories** (such as "musical instruments"), which contain members (such as pianos and guitars) that are dissimilar in several respects. At the same time, basic-level categories are most differentiated from one another, especially relative to subordinate categories. "Grand piano" and "upright piano" are two categories at the **subordinate level of categories;** these categories are less distinct than are two basic-level categories, such as "piano" and "guitar." The list in Table 8-2 presents examples of basic-level categories, along with related superordinate and subordinate categories.

Table 8-2 Basic-Level Categories with Related Superordinate and Subordinate Categories

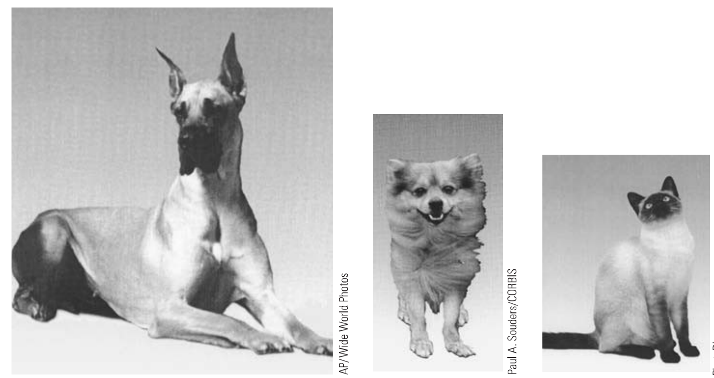
Superordinate	*Basic Level*	*Subordinate*
Musical instrument	Guitar	Classical guitar
		Folk guitar
	Piano	Grand piano
		Upright piano
	Drum	Bass drum
		Kettle drum
Fruit	Apple	Delicious apple
		McIntosh apple
	Peach	Cling peach
		Freestone peach
	Grapes	Concord grapes
		Green seedless grapes
Tool	Hammer	Claw hammer
		Ball-peen hammer
	Saw	Hack handsaw
		Cross-cutting handsaw
	Screwdriver	Phillips screwdriver
		Regular screwdriver
Clothing	Pants	Levis
		Double-knit pants
	Socks	Knee socks
		Ankle socks
	Shirt	Dress shirt
		Knit shirt
Furniture	Table	Kitchen table
		Dining room table
	Lamp	Floor lamp
		Desk lamp
	Chair	Kitchen chair
		Living room chair
Vehicle	Car	Sports car
		Four-door sedan
	Bus	City bus
		Cross-country bus
	Truck	Pickup truck
		Tractor-trailer truck

SOURCE: Rosch, Mervis, et al. (1976, p. 388).

The prototype view does a very good job at explaining why certain members of a category are seen as more typical than others. It also explains why people have a hard time providing strict definitions of their concepts: Strict definitions do not exist. Finally, the prototype view can explain why some classifications are especially easy to make and others are unclear. Take tomatoes, which some people classify as a vegetable and others classify as a fruit. Tomatoes are often eaten with other vegetables instead of with other fruits, and they share some similarities with other vegetables. However, to a biologist, tomatoes are a fruit because they develop from the flower of the plant (technically, the pistil). Vegetables, in contrast, are any nonreproductive parts of a plant, such as the stem or root. The prototype view explains the ambiguity of tomatoes: They share features both with vegetables (leading to classification as a vegetable) and with fruits (leading to classification as a fruit).

The prototype view is not wholly free of problems. For one thing, it fails to capture people's knowledge about the limits of conceptual boundaries. To illustrate, even though a Pomeranian seems in many ways more similar to a Siamese cat than to a Great Dane, the Pomeranian and Great Dane are classified together as dogs (Komatsu, 1992). The prototype view has a hard time telling us why. Unlike the classical view, which sets constraints or boundaries around which things can and can't belong to a category, the prototype view does not specify clear constraints.

Rosch and colleagues (Rosch, 1973; Rosch & Mervis, 1975; Rosch, Mervis, et al., 1976) have argued that some constraints around different categories come



AP/Wide World Photos

Paul A. Souders/CORBIS

PhotoDisc

A Great Dane, a Pomeranian, and a Siamese cat: Even though the overall similarity may be greater between the latter two, the former two are classified together in the category "dogs."

from the environment itself. Having wings and being able to fly, for example, tend to co-occur, often in those things we call *birds* (but also in airplanes, butterflies, and insects). Boundaries between categories, then, come not just from us as cognitive processors of information but from the way the world works: Certain patterns of attributes or features occur in the world, and others don't (Komatsu, 1992; Neisser, 1987). People's main job in categorizing, then, is to pick up information about the world's regularities, not to impose arbitrary groupings, as the classical view might imply. (The idea of "picking up information" about the world might remind the alert student of Gibsonian theories of perception, discussed in Chapter 3.)

A second problem for the prototype view has to do with typicality ratings. Barsalou (1985, 1987) and Roth and Shoben (1983) showed that the typicality of an instance depends to some extent on context. So although a robin may be seen as a typical bird in the context of birds you see in the neighborhood, it is atypical of birds you see in a barnyard. These findings contrast with the idea that a member of a category has a certain level of typicality. Instead, typicality apparently varies with the way the concept itself is being thought about.

Studies by Armstrong, Gleitman, and Gleitman (1983) demonstrated additional problems with typicality ratings. In these studies, the investigators asked participants to rate the typicality of instances of both natural concepts (such as "vehicle" or "fruit") previously studied by Rosch and her colleagues and of well-defined concepts (such as "even number," "female," "geometric figure"). Armstrong et al. found that participants happily rated the typicality of members of well-defined categories, generally agreeing that 3 is a more typical odd number than 57, for example. The same participants also agreed, however, that the category "odd number" was well defined and that it makes little sense to talk about degree of membership in the category: Numbers either are or are not odd. The investigators concluded that the typicality ratings task is flawed, at least for discovering the underlying representation of concepts.

The Exemplar View

The previous two views of concepts both hold that concepts are some sort of mental abstraction or summary. In other words, individual instances are not specifically stored or mentally represented but instead are averaged into some sort of composite representation. The **exemplar view of concepts** makes just the opposite assumption: It asserts that concepts include representations of at least some actual individual instances. The exemplar approach assumes that people categorize new instances by comparing them to representations of previously stored instances, called *exemplars*. That is, people store representations of actual instances (Fido, the golden retriever with the long ears; Rover, the black and white sheltie who's missing a tail due to an unfortunate encounter

with a raccoon; Precious, the Yorkshire terrier who always has painted toenails and a bow in his hair).

Like the prototype view, it thus explains people's inability to state necessary and defining features: There are none to be stated. It also explains why people may have difficulty categorizing unclear, atypical instances: Such instances are similar to exemplars from different categories (for example, tomato is similar both to fruit exemplars, such as oranges or apples, and to vegetable exemplars, such as beets or squash) or are not similar enough to any known exemplars (Medin & Smith, 1984). Typical instances are thought to be more likely to be stored than less typical ones (Mervis, 1980) or to be more similar to stored exemplars, or both. This explains why people are faster to process information about typical instances. So, in trying to retrieve information about a typical instance, it is faster to find very similar stored exemplars. Atypical instances, in contrast, being rather dissimilar from stored exemplars, take longer to process.

The biggest problem with the exemplar view is that, like the prototype view, it is too unconstrained. It fails to specify, for example, which instances will eventually be stored as exemplars and which will not. It also does not explain how different exemplars are "called to mind" at the time of categorization. However, many psychologists believe people often store information about some specific category members in their conceptual representations, as we will see later.

The Schemata View

We have already touched on the concept of a schema, or organized framework for representing knowledge, in talking about Bartlett's (1932) work on people's memories for stories (see Chapters 6 and 7), so our coverage here will be brief. Be sure you've understood the material from those chapters on schemata as you read what is here.

The schemata view of concepts is that concepts are schemata—frameworks of knowledge that have roles, slots, variables, and so on. Schemata can embed themselves in one another hierarchically. Thus any schema can have subschemata and/or superschemata. The "meeting a college roommate for the first time" schema can be a subschema of an "orientation to college" schema, which may be embedded in an "attending college" schema, and so on. Similarly, the "meeting a college roommate for the first time" schema may contain subschemata of "dorm room," "meeting new person," and "roommate" embedded within it. The schema for "dog" may be a part of the schemata for "mammal," "pet," "animal," and "living thing"; it may contain subschemata such as "fur," "paws," and "wagging tail." The notion of schemata as underlying organizational units of memory has had significant impact on cognitive psychologists' thinking about how memory is organized and concepts represented. Some (Komatsu,

1992) have seen the **schemata/scripts view of concepts** as sharing features with both the prototype view (in that both schemata and prototypes store information that is abstracted across instances) and the exemplar view (in that both schemata and exemplars store information about actual instances).

The schemata view shares some of the problems facing the prototype and exemplar views. It does not specify clear enough boundaries among individual schemata. Moreover, some psychologists argue that in its current state the schema framework is not sufficiently delineated to be empirically testable (Horton & Mills, 1984). Answers to the following questions are still needed: What kinds of experiences lead to the formation of new schemata? How are schemata modified with experience? How do people know which schemata to call up in different situations—that is, what sorts of environmental cues are used?

The Knowledge-Based View

A number of cognitive psychologists (Keil, 1989; Lin & Murphy, 2001; Murphy & Medin, 1985) have argued that concepts have much more to do with people's knowledge and worldviews than previously recognized. Murphy and Medin (1985) suggested that the relationship between a concept and examples of the concept is analogous to the relationship between a theory and data supporting that theory. The idea of the **knowledge-based view of concepts** is that a person classifying objects and events doesn't just compare features or physical aspects of the objects and events to features or aspects of stored representations. Instead, the person uses his or her knowledge of how the concept is organized to justify the classification and to explain why certain instances happen to go together in the same category. The knowledge-based view helps explain how an apparently disparate collection of objects can form a coherent category in particular circumstances.

To take an example from Barsalou (1983), consider the category comprising children, pets, photo albums, family heirlooms, and cash. On the face of it, these things don't seem to go together very well, but in the context of a scenario in which a fire is about to engulf a house, these things fall neatly into the category "things to save." We know that each object mentioned is precious to its owner or parents and also irreplaceable. Notice, however, that the category becomes coherent only when we know its purpose.

Recall that the prototype, exemplar, and schemata/scripts approaches to concepts and categories fail to offer much of an answer to the question of how things in the same category go together. The knowledge-based view proposes that people's theories or mental explanations about the world are intertwined with their concepts and provide the basis for categorization (Heit, 1997). This view lets people explain to themselves and to others the instances that go together and why, the features or aspects of instances that are important and why, and the features or aspects that are irrelevant and why.

The five approaches to conceptual structure just reviewed have been themselves categorized into two major types: similarity-based and explanation-based (Komatsu, 1992). The similarity-based category consists of the classical, prototype, and exemplar views (and some parts of the schemata/scripts view). It includes approaches in which categorization is assumed to be based on the similarity of an instance to some abstract specification of the category (such as a definition or a prototype) or to one or more stored exemplars.

However, to say that objects are categorized on the basis of similarity raises some problems, some of which Goodman (1972) pointed out. Consider two objects, a fork and a spoon. We say they are similar, probably because they share many properties: Both are made of metal, both are less than a foot long, and both are used as eating utensils. Now consider two other objects, a plum and a lawnmower. Are these similar? Well, they share several properties: Both weigh less than 100 kilos (and in fact, both weigh less than 101 kilos, 102 kilos, and so forth). In fact, these two apparently dissimilar items share an infinite number of properties (Hahn & Chater, 1997). But the property of weighing less than 100 kilos seems somehow beside the point when you are evaluating the similarity between a plum and a lawnmower. The key point is that similarity is meaningful only in certain respects. But Goodman concluded that the term *similarity* is pretty empty without some specification of what the relevant respects are.

Komatsu (1992) defined a different type of approach to concepts, which he called the *explanation-based category,* comprising some of the schemata/scripts view and some of the knowledge-based view. In this approach to the study of concepts, people are seen as basing classifications on meaningful relationships among instances and categories. The contrast between the similarity-based and the explanation-based approaches has to do with the degree to which people focus on superficial, perceptual information about a particular object versus the degree to which they focus on deeper, knowledge-derived information about an object's function or role.

The five approaches to concepts differ on several dimensions. The first dimension is the cognitive economy of the mental representation. Recall our discussion of cognitive economy from Chapter 7. The idea is to save on mental resources (such as storage space, processing time) by limiting the amount of information we must store. If we treated every single object or event as completely unique, thereby forming a unique mental representation for each, we would not be using our cognitive resources very economically.

In contrast, if we categorized all objects into one category (called "things"), the category wouldn't be very informative. So any theory of concepts and categorization must strike a balance between cognitive economy and informativeness (Komatsu, 1992). At the same time, any theory of concepts must explain a concept or category's coherence—what holds the class of things together into a natural grouping. Some approaches, such as the classical approach, do this very directly; others have fuzzier boundaries around and between concepts.

Thus far, we have looked at different proposals for what concepts are—their nature and structure. In the next section, we will examine empirical studies looking at how concepts are actually formed and used. Presumably, understanding something about the ways in which people classify new instances can shed light on the nature of concepts. The studies we'll review next will help us think more carefully about the five approaches just discussed.

■ FORMING NEW CONCEPTS AND CLASSIFYING NEW INSTANCES

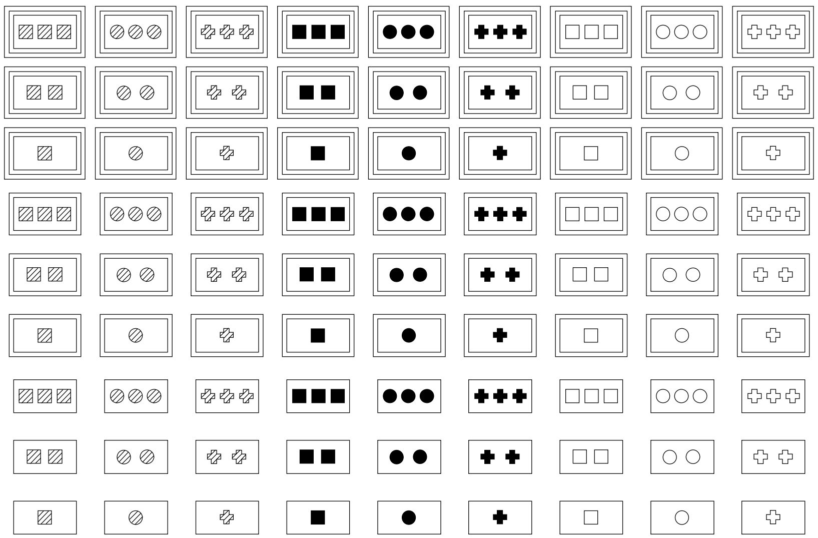
To have a concept of something is to group similar things together, to treat in more or less similar ways members of the category that the concept includes. To form a concept, people must have some basis for generalization, for grouping certain things but not others together. When you think about it, forming a concept is a remarkable cognitive achievement. It requires that we figure out which attributes or features of things are relevant and which should be ignored. Often we must carry out the task with very little feedback. In this section, we'll explore some investigations of how people manage this complex undertaking. Throughout, we'll see that psychologists' assumptions about how concepts are mentally represented have influenced their views on how people acquire or form new concepts.

Concept Attainment Strategies

Bruner, Goodnow, and Austin (1956) conducted some of the earliest work on how people form (or, in their terminology, "attain") concepts. They saw several components in the process: acquiring the information necessary to isolate and learn a concept, retaining the information for later use, and transforming the information to make it usable when testing ideas about new possible instances.

Bruner et al. (1956) studied the ways people attained concepts, using cards depicting differing geometric figures, as shown in Figure 8-2. Note that each card has one of three shapes (circle, square, or cross), one of three colors (here, black, white, or striped), different numbers of shapes (one, two, or three), and different numbers of borders around the shapes (one, two, or three). The experimenter first placed before each participant all the cards appearing in Figure 8-2. Participants were told the experimenter had in mind a certain concept, such as "black circles" or "all cards containing two borders and striped figures." Participants were then shown one card that illustrated the concept—in other

FIGURE 8-2 ■ *Stimuli used by Bruner et al. (1956).*
SOURCE: Bruner et al. (1956).



words, a positive instance. Their subsequent task was to test the other cards, one at a time, for inclusion in the category. The experimenter provided feedback after each card was considered. Each person was asked to determine the nature of the concept as efficiently as possible, choosing cards in any order and offering hypotheses whenever he felt comfortable doing so.

From the participants' choices, Bruner and colleagues tried to determine the strategies used. Bruner et al. (1956) described distinct strategies that could be used to perform the task. They called one strategy *simultaneous scanning*. People who pursued this strategy used each card to test and rule out multiple hypotheses. The strategy required participants to figure out ahead of time the hypothesis to which each card was relevant and to consider carefully how to eliminate the maximum number of hypotheses by choosing the optimal card at each point in the process. As you might expect, this strategy is difficult to use and makes heavy demands on working memory.

A second strategy, *successive scanning*, appeared more manageable. Here, a participant tested one hypothesis at a time. For example, he first tried to see, by choosing appropriate cards, if the concept was "black figures"; if he became convinced this was the wrong concept, he or she tested another idea, and so on, until amassing enough evidence that the correct concept had been attained. The contrast between simultaneous and successive scanning is that the former involves testing a number of ideas at the same time; the latter involves testing ideas one at a time. Successive scanning is therefore less efficient but more cognitively manageable.

A third strategy was called *conservative focusing*. It consisted of finding a card that illustrated the concept (called the "focus" card), then choosing to test other cards that varied from it in only one aspect. For instance, if the focus card had two black crosses and one border, the participant might next select one of the following cards: a card with two black circles and one border; a card with one black cross and one border; a card with two black crosses and two borders; or a card with two white crosses and one border. If any of these cards was also a member of the category, then the participant could logically eliminate the changed attribute as being relevant to the concept. For example, if the card with two white crosses and one border was also a member of the category, then the participant knew color did not define the concept. This strategy is interesting because it is both efficient and relatively easy, but unless the cards are laid out in an orderly fashion so a particular one can be easily located, it may be difficult to carry out.

Bruner et al. (1956) found that the effectiveness of each of these strategies depended to some extent on the task conditions. For instance, when participants had to do the problem "in their heads," without the cards' being displayed, those using scanning strategies had more trouble than did participants who could lay out the cards on a table to refer to as they worked. The strategy participants adopted also depended to some extent on the task, such as whether the cards were initially arranged in an orderly or random way.

Aficionados of the game Mastermind might recognize that it has many basic similarities to the Bruner et al. (1956) concept attainment task. Laughlin, Lange, and Adamopoulos (1982) studied college students playing a simplified version of the game and found that the two dominant strategies that emerged were similar to Bruner and colleagues' conservative focusing and simultaneous scanning. Participants who used these strategies had more success at playing the game than did those who did not, with the conservative focusing strategy being the most successful.

Notice the kind of concept being learned in these tasks. In all the tasks, valid instances of the category share necessary and sufficient features. In fact, the concepts involved in these experiments were what philosophers and psychologists might call *nominal:* concepts that have precise definitions (Schwartz, 1980). The results of the Bruner et al. (1956) studies suggest that when concepts are defined with necessary and sufficient features, people form representations that include necessary and sufficient features. We will see later that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The game of Mastermind is a real-life example of the concept attainment task used by Bruner et al. (1956).

when people acquire other kinds of concepts, especially those that do not have clear-cut definitions, their acquisition strategies vary.

Acquiring Prototypes

You may remember that in Chapter 3 we reviewed experiments that Posner and Keele (1968) performed on people's ability to classify dot patterns. Their study suggested that, at least in some circumstances, people are able to, and find it natural to, form prototypes and that they are better able to classify actual prototypes than to classify previously encountered instances. In part of the study, the experimenters began with four specific dot patterns (prototypes): a triangle, the letters *M* and *F,* and a random pattern. Next they created distortions of these patterns by varying the position of the dots. They also varied the number of dots moved, as well as the amount of distortion, sometimes moving each dot very slightly, other times moving dots a great distance.

Undergraduates learned to classify correctly either low-distortion or moderate-distortion stimuli but were never shown the original prototypes. The assumption was that students who saw the low-distortion stimuli ought to have had a better conception of the prototypes than those who saw the moderate-distortion stimuli. Conversely, students in the moderate-distortion group ought to have had a better sense of how much variation there could be from the prototype. Both groups of students were later shown some novel, high-distortion stimuli. Students in the moderate-distortion group were significantly better able to classify these patterns. Further, all students found it easier to classify novel patterns that were similar to prototypes.

These results suggest two things. First, people do form and use prototypes, even when given distorted instances during the learning phase. Second, learning about category variability may be at least as important as learning about prototypes, especially if categorizations are to be made later of new instances that vary a great deal from the prototype.

The results obtained by Posner and Keele (1968) appear very different from those of Bruner et al. (1956). What might account for this difference? Two important differences are apparently the type of stimuli being used and the type of concepts being acquired. Notice that the Bruner et al. task involved concepts with clear-cut definitions; the Posner and Keele task did not. This latter task involved learning concepts that were defined by similarity to previous examples. When categories are defined in this way, people apparently learn to classify by forming and using mental representations of prototypes. Taken as a whole, the results from these studies reinforce the idea that the way people form and learn concepts depends critically on the instances and the categories they must work with.

Implicit Concept Learning

The results just described imply that people can and do form and use prototypes, at least under certain conditions and with certain stimuli. This raises the question of whether participants ever retain and make use of information about specific exemplars. Arthur Reber (1967, 1976) conducted a series of studies bearing on this issue. In his experiments, participants were given strings of letters to learn, such as the ones shown in Figure 8-3(A). Unknown to people in some of the experimental groups, the letters were not randomly chosen but were generated by a structure sharing similarities with certain kinds of language grammars.

Figure 8-3(B) depicts one such grammar. To generate a "legal" letter string—that is, in accord with the grammar—imagine yourself starting at the path marked "In" and moving to the path marked "Out," following the directional arrows as you go. As you take each path, you add the letter of that path to your string. So the first letter of a "legal" string is always either a *T* or a *V*. Notice two loops in the grammar, one labeled *P* and one *X*. These loops can be followed any number of times (each time adding either a *P* or an *X* to the letter string), allowing letter strings that are infinitely long.

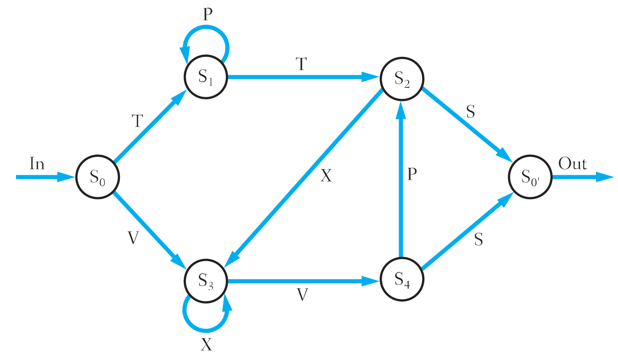
FIGURE 8-3 ■ *Possible stimuli (A) and their underlying "grammar" (B) used by Reber (1967).*

SOURCE: Reber (1967, p. 856).

T P P T X V S   T T X X V S

V X X X V S   V X X V P S

(A)



(B)

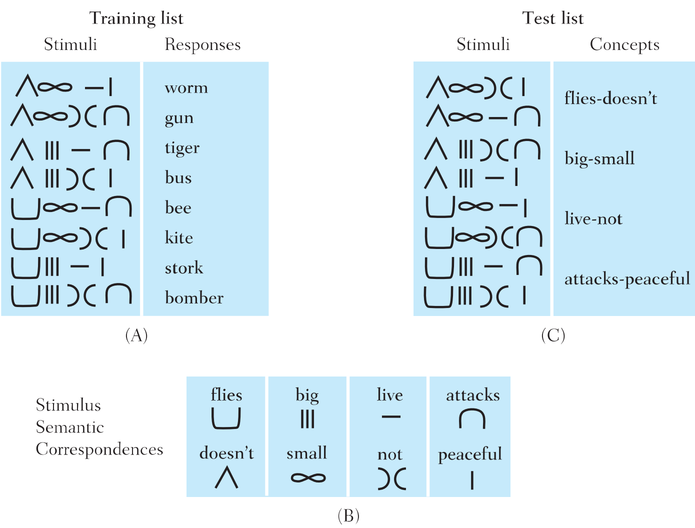
Reber (1967, 1976) found, first, that participants learning letter strings that followed the grammar made fewer errors than did control participants learning random letter strings. More surprising, participants who were told ahead of time that letter strings followed certain complex rules remembered strings less well than participants who were simply asked to memorize particular letter strings but were not told anything about the strings' following a structure. Reber concluded that when complex underlying structures exist (such as his grammar), people are better off memorizing exemplars than trying to figure out what the structure is, primarily because participants who try to guess the structure often induce or invent incorrect rules or structures.

Brooks (1978, 1987) believed that the processes Reber (1967) discovered are at work much of the time in ordinary cognition. Brooks called these processes **nonanalytic concept formation,** in contrast to analytic (logical, scientific, focused) concept formation such as exhibited by research participants in the Bruner et al. (1956) study. Nonanalytic concept formation, also sometimes called **implicit learning,** requires that people pay attention to individual exemplars, storing information about and representations of them in memory. Later classification is done by comparing new instances to the representations, drawing analogies between new and old.

In one study, Brooks (1978) had participants perform a paired-associates learning task, learning to associate hieroglyphic symbol strings with English words. Figure 8-4(A) presents examples of his stimuli. Each symbol in the string had a certain meaning, as shown in Figure 8-4(B), but participants were not alerted to this fact. Later they were unexpectedly given new strings, such as those in Figure 8-4(C), and were asked four questions: Does it fly? Is it big? Is it alive? Does it attack? Most of the participants reported they answered the questions by thinking of a previous example that looked similar. However, they generally couldn't point to any particular symbol in the string as a basis for their response.

FIGURE 8-4 ■ *Stimuli from Brooks's (1978) experiments.*

SOURCE: Brooks (1978).



Brooks's results pose a puzzle for cognitive psychologists. Apparently, participants sometimes explicitly test specific hypotheses when forming concepts (as in the Bruner et al., 1956, experiments), sometimes they form prototypes (as in the Posner & Keele, 1968, experiments), and sometimes they memorize exemplars (as in the Reber, 1967, 1976, and Brooks, 1978, experiments). The question is, When and why do people adopt such different approaches?

Brooks (1978) believed the answer had to do with the concept formation task itself. Some simple laboratory tasks, such as the one used by Bruner et al. (1956), seem to lead participants to adopt an analytical, hypothesis-testing framework. Other, more complex stimuli lead people to abandon this approach for another. Brooks went on to describe five factors that encourage people to store information about individual exemplars.

The first factor involves task requirements to learn information that distinguishes among individual instances. Brooks (1978) reminded us that in natural situations, different items in the same category must sometimes be treated differently. It is all very well to recognize that Rover, the lovable family mutt, and Killer, the attack dog for the company down the street, are both dogs, but the child or adult who treats them as interchangeable could be in for a painful surprise.

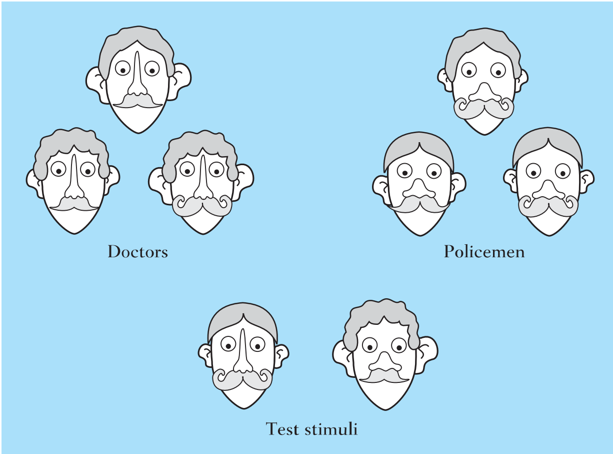
A second factor involves the original learning situation. In many real-life situations, instances are not presented one at a time in rapid succession (as in many laboratory experiments). Instead, the same instance (Rover, the family mutt) may appear repeatedly (especially at mealtimes!), affording the person a chance to get to know certain instances very well.

Third, some stimuli lend themselves to hypothesis testing better than others do. Notice that in the Bruner et al. (1956) stimuli, instances varied on only four dimensions. In real life, things vary in many complicated ways. Often, the relevant dimensions of variation are not apparent to the novice, an idea we discussed in the section on perceptual learning. A fourth factor is that in real-life concept learning, instances may belong to a number of categories all at the same time. Rover might belong to any of the following categories: "dog," "family pet," "partner to take to obedience classes," "source of mud on rainy days," or even "incurrer of large food bills." Finally, Brooks pointed out that in natural settings, we learn about instances without knowing how we will be called on to use the information later.

Kemler Nelson (1984) also argued that much of our real-life conceptual knowledge is acquired nonanalytically rather than analytically. Her research has shown that children are especially likely to use this mode of concept learning, as are adults when they are not allowed to devote many cognitive resources to the task—for example, when they are forced to process information more rapidly than they might otherwise do (Smith & Kemler, 1984).

Furthermore, Kemler Nelson (1984) believed that nonanalytic concept formation is especially likely with materials that have strong family resemblance structures. Participants in one of her experiments were presented with artificial faces, such as those in Figure 8-5. The faces varied on four attributes—curliness of hair, length of nose, size of ears, and breadth of mustache—with each attribute having three values (such as slightly curly mustache, medium curly mustache, and very curly mustache). Participants learned which faces belonged to the category "doctors" and which to the category "policemen." Faces presented

FIGURE 8-5 ■ *Stimuli used by Kemler Nelson (1984).*
SOURCE: Kemler Nelson (1984, p. 742).



during the learning phase were carefully chosen, such that one attribute distinguished between the two categories (in this example, length of nose: Doctors have long noses; policemen, short ones). At the same time, the two categories differed in their family resemblance structure, although the difference was not absolute. In this example, doctors tend to have slightly curly mustaches, large ears, and broad mustaches, and policemen, very curly mustaches, small ears, and thinner mustaches, although not every instance shared all these features.

In the subsequent test phase, participants were presented with a number of test faces, including two "critical" test faces, and were asked to classify each one. These faces pitted the criterion feature (such as length of nose) against the family resemblance structure. The way people classified these faces revealed the basis of their classification: If they used a criterion feature, they classified the faces one way; if they used family resemblance structure, they were more likely to make a different classification. In this example (see Figure 8-5 again), note that the left test face has a long nose, suggesting it belongs to the "doctor" category, but that it has more overall similarity to faces in the "policemen" category; the reverse is true for the right face.

Some of Kemler Nelson's (1984) participants were explicitly told to search for a means of distinguishing between doctors and policemen; others were

simply asked to learn to recognize the pictures. Kemler Nelson found the latter group was especially likely to use family resemblance structure as a basis for classification; approximately 60% did so. Of those in the former group, only 46% used that approach. She concluded that both the kinds of concepts being learned and the instructions about the task influence the concept acquisition strategy that people adopt.

Using and Forming Scripts

In Chapter 7, we discussed the concept of scripts, schemata for routine events. If you and each of your classmates listed your knowledge of what happens when you purchase a meal at McDonald's, all the lists would likely show a very high level of agreement, in terms of what events and actions you mention, the order in which you mention them, and the level of description you use. My "McDonald's script" (well practiced of late because my four-year-old daughter loves Happy Meals) is roughly as follows: You enter; walk to the counter; wait in line; order food; pay the counterperson; wait while your order is assembled; carry the tray of food to the counter that holds napkins, straws, and ketchup; gather those supplies; find a table; sit and eat; gather the trash onto the tray; take the tray to the trash bin; dump the contents of the tray into the trash bin; leave. There are some personal variations to my McDonald's script, of course (for instance, checking the toy that comes with my daughter's Happy Meal and asking to exchange it if it's one she already has), but for the most part, I would bet my script overlaps with yours a great deal. Notice I don't specify details at the level of how many steps I need to walk or whether I turn right or left—these details vary at different McDonald's locations and don't much affect the script. The point is, my McDonald's script would work at your McDonald's, and vice versa.

Bower, Black, and Turner (1979) investigated how much people typically use scripts. They first asked participants to write their scripts for a number of specific events: going to a restaurant, attending a lecture, getting up in the morning, grocery shopping, visiting a doctor. They compared the notes generated by all the participants and found a high degree of overlap in what people mentioned. The participants generally agreed about which characters to describe, which props and actions to mention, and the order in which different actions would occur.

The investigators also found a high degree of agreement in description level. Thus most people would mention "eating the food" instead of "picking up a spoon, dipping it into soup, raising the spoon to lips, and sipping." In another study, Bower et al. (1979) showed that if information from a story was presented in scrambled order, people tended to recall it in the scripted order. In a further experiment, the investigators presented stories that mentioned only some of the events in a typical script. They found that in a later recall task, people often "recalled" information that wasn't in the story but was in the relevant script. Rizzella and O'Brien (2002) found that when people were given a narrative text to read and remember, central concepts relevant to the script (such as in a restaurant script, being served a meal) were typically better remembered than concepts of less importance to the script (such as giving one's name to a hostess).

Psychological Essentialism

A proposal by Medin (1989), drawing on work by the philosopher Hilary Putnam (1975), has examined people's reliance on underlying nature as a basis for many concepts. Medin proposed a framework he called **psychological essentialism** and described several assumptions. The first is that people generally act as if objects, people, or events have certain essences or underlying natures that make them what they are. Presumably, for instance, a human being is a human being by virtue of having a certain molecular structure. That essence constrains or limits the kinds of variation that different instances of a category can show. So, for instance, people can vary in height, weight, hair color, eye color, bone structure, and the like, but they must have certain other properties in common by virtue of the underlying essence they share. People's theories about the essences of various categories help them connect deeper properties (such as the structure of DNA) to more superficial properties (such as eye color or hair color). For example, Medin pointed out that although most of us believe that the categories "male" and "female" are genetically determined, most of us look at characteristics such as hair length, facial hair, and so on, rather than conducting genetic tests when classifying a new person as a woman or a man. We may make errors in using superficial characteristics, but we probably won't often be led astray.

People's knowledge of the essence of a category varies by level of expertise. Biologists, in general, know a lot more about the genetic structure of a human being than do laypeople. For this reason, experts can generally be expected to make different and more accurate classifications, especially if the criteria for the classifications are subtle. Medin's (1989) idea is that classifying on the basis of perceptual or other superficial similarity may be a strategy that can be pretty effective much of the time. Still, when the situation calls for it and if the expertise is possessed, people classify on the basis of deeper principles. This suggestion implies, then, that people's classification of instances will change as they become more experienced and knowledgeable—an idea that fits well with our discussion of perceptual learning, as well as with the currently available data.

The way people acquire and mentally represent concepts may also vary as a function of what the concepts are (Murphy, 2005). Some psychologists have

adopted the perspective of philosophers in distinguishing among kinds of concepts. **Nominal-kind concepts** include concepts that have clear definitions. **Natural-kind concepts,** such as "gold" or "tiger," are of things naturally occurring in some environment (Putnam, 1975). A third kind of concept is **artifact concepts,** things constructed to serve some function or accomplish some task (see Keil, 1989; Schwartz, 1978, 1979, 1980). Different information may be represented in different kinds of concepts.

For instance, nominal-kind concepts (such as the ones Bruner taught participants in his studies) may include information about necessary and sufficient features, because these things exist as part of the concept definition. Natural-kind concepts may include more information about definitional or essential features, especially about molecular or chromosomal structure. Natural-kind concepts may also be more likely to have a family resemblance structure but can be equally well explained within a knowledge-based approach.

Artifact concepts, in contrast, may highlight information about the object's purpose or function and may be adequately described only within the knowledge-based approach. In one study, Barton and Komatsu (1989) presented participants with five natural-kind concepts (such as *goat, water, gold*) and five artifacts (such as *TV, pencil, mirror*). With each concept, they asked the participants to imagine different transformations. Some transformations were phrased in terms of function or purpose (for example, a female goat that did not give milk or a TV with no visible picture); others were in terms of physical features (for example, gold that was red in color or a pencil that was not cylindrical). A third type of change was molecular (for example, water that did not consist of the formula H_2O, or a mirror not made out of glass). The investigators found that with natural-kind terms participants were most sensitive to molecular transformations, whereas with artifact terms they were most sensitive to functional changes. Apparently, then, all concepts are not treated equally, and, under at least some conditions, people use their knowledge about why instances of a category should be grouped together in their representation of the related concept (Medin, Lynch, & Solomon, 2000).

Summary

1. Categories are classes of similar objects, events, or patterns. Concepts are mental representations of those categories. Concepts are thought to help us order our knowledge and to relate new objects or patterns to previously encountered ones.
2. There are five distinct approaches to the study of concepts. These have been themselves categorized into two major types: similarity-based and explanation-based (Komatsu, 1992).

3. The similarity-based category, comprising the classical, prototype, and exemplar views (and some parts of the schemata view), includes the approaches in which categorization is assumed to be based on the similarity of an instance to some abstract specification of the category (for example, a definition or a prototype) or to one or more stored exemplars.
4. The explanation-based category, comprising aspects of the schemata/scripts view and aspects of the knowledge-based view, instead sees people as classifying instances based on meaningful relationships among instances and categories.
5. The classical approach to concepts posits that each concept is defined by a set of necessary and sufficient features.
6. The prototype approach to concepts holds that we categorize objects by comparing them to mental abstractions, called prototypes, which are idealized representations of some class of objects or events.
7. The exemplar approach to concepts assumes we store specific individual instances and use these stored representations to categorize.
8. The schemata/scripts view regards concepts as schemata, packets of information with specific parts, that fill in default values for aspects of the situation.
9. Proponents of the knowledge-based view of concepts hold that people use their own theories to guide their classification of objects.
10. When people are explicitly asked to form concepts and to search for underlying rules or features, they seem to acquire and use different kinds of information from what they use when left to their own exploration. This raises the question of applicability of very traditional laboratory-based investigations of concept formation to the processes people use outside the laboratory. What gets learned depends, apparently, on the original learning materials, the task instructions, and the learner's anticipation of how the learned information will be used in the future. As in other areas of cognition, then, the way people process information is flexible and varies with the situation and the purpose of the task.

Review Questions

1. Describe the distinction many cognitive psychologists make between concepts and categories. What are the cognitive benefits of having concepts? Explain.
2. Contrast the classical, prototype, and exemplar proposals for how concepts are mentally represented. What kinds of arguments and/or empirical findings support each? What kinds of arguments and/or empirical data are troublesome for each?

3. Describe what a family resemblance structure is and how it relates to the prototype approach to concepts.
4. Compare and contrast the schemata view and the knowledge-based view of concepts. Are the two compatible? How or how not?
5. Briefly review Reber's work on implicit learning and its implications for concept formation.
6. Give some new examples of scripts, and justify your examples.
7. Discuss this statement: "Any approach to concepts must strike some balance between cognitive economy and informativeness."

Key Terms

artifact concept
basic level of categorization
category
classical view of concepts
concept
exemplar view of concepts
family resemblance structure of concepts
features
implicit learning
knowledge-based view of concepts
natural-kind concept
nominal-kind concept
nonanalytic concept formation
prototype
prototype view of concepts
psychological essentialism
schemata/scripts view of concepts
subordinate level of categories
superordinate level of categories

CogLab Demonstrations

To check your knowledge of the key concepts in this chapter, take the chapter quiz at http://www.thomsonedu.com/psychology/galotti. Also explore the hot links that provide more information.

The **Prototypes** demonstration provides you with an experience similar to those of research participants in Posner and Keele's classic dot-pattern categorization study.

Web Resources

Visit our website. Go to http://www.thomsonedu.com/psychology/galotti, where you will find online resources directly linked to your book, including quizzes, flashcards, crossword puzzles, and glossaries.