Cognitive Psychology

Robert J. Sternberg
Tufts University

with contributions of the
Investigating Cognitive Psychology boxes by

Jeff Mio
California State University–Pomona
EXPLORING COGNITIVE PSYCHOLOGY

THE NATURE OF ATTENTION AND CONSCIOUSNESS
- Preconscious Processing
- Controlled versus Automatic Processes
- Habituation and Adaptation

ATTENTION
- Signal Detection
- The Nature of Signal Detection
- Vigilance
- Search

SELECTIVE AND DIVIDED ATTENTION
- Basic Paradigms for Studying Selective Attention
- Filter and Bottleneck Theories of Selective Attention
- Attentional-Resource Theories of Selective Attention
- Additional Considerations in Selective Attention
- Divided Attention
- Consciousness of Complex Mental Processes
- Attention Deficit Hyperactivity Disorder

COGNITIVE NEUROSCIENTIFIC APPROACHES TO ATTENTION AND CONSCIOUSNESS
- Spatial Neglect
- Attentional Systems
- Using Event-Related Potentials to Measure Attention
- A Psychopharmacological Approach

KEY THEMES

SUMMARY

THINKING ABOUT THINKING: FACTUAL, ANALYTICAL, CREATIVE, AND PRACTICAL QUESTIONS

KEY TERMS

ANNOTATED SUGGESTED READINGS
Attention is the taking possession of the mind, in clear and vivid form, of one out of what seem several simultaneously possible objects or trains of thoughts. . . . It implies withdrawal from some things in order to deal effectively with others.

—William James, *Principles of Psychology*

Attention is the means by which we actively process a limited amount of information from the enormous amount of information available through our senses, our stored memories, and our other cognitive processes (De Weerd, 2003a; Duncan, 1999; Motter, 1999; Posner & Fernandez-Duque, 1999; Rao, 2003). It includes both conscious and unconscious processes. Conscious processes are relatively easy to study in many cases. Unconscious processes are harder to study simply because you are not conscious of them (Jacoby, Lindsay, & Toth, 1992; Merikle, 2000). For example, you always have available to you your memory of where you slept when you were 10 years old, but you probably do not often process that information actively. Similarly, you usually have available a wealth of sensory information (e.g., in your body and in your peripheral vision at this very moment). But you attend to only a limited amount of the available sensory information at a given time (Figure 4.1). Moreover, you have very little reliable information about what happens when you sleep. Additionally, the contents of attention can reside either within or outside of awareness (Davies, 1999; Davies & Humphreys, 1993; Metzinger, 1995).

There are many advantages to having attentional processes of some sort. There seem to be at least some limits to our mental resources. There are limits as well to the amount of information on which we can focus those mental resources at any one time. The psychological phenomenon of attention allows us to use our limited mental resources judiciously. By dimming the lights on many stimuli from outside (sensations) and inside (thoughts and memories), we can highlight the stimuli that interest us. This heightened focus increases the likelihood that we can respond speedily and accurately to interesting stimuli. Heightened attention also paves the way for memory
processes. We are more likely to remember information to which we paid attention than information we ignored.

**Consciousness** includes both the feeling of awareness and the content of awareness, some of which may be under the focus of attention (Block, Flanagan, & Güzeldere, 1997; Bourguignon, 2000; Chalmers, 1995, 1996; Cohen & Schooler, 1997; Farthing, 1992, 2000; Marcel & Bisiach, 1988; Nelkin, 1996; Peacocke, 1998; Taylor, 2002; Velmans, 1996). Therefore, attention and consciousness form two partially overlapping sets (DiGirolamo & Griffin, 2003). At one time, psychologists believed that attention was the same thing as consciousness. Now, however, they acknowledge that some active attentional processing of sensory information, and the remembered information, proceeds without our conscious awareness (Shear, 1997; Tye, 1995). For example, at this time in your life, writing your own name requires no conscious awareness. You may write it while consciously engaged in other activities—although not if you are completely unconscious. In contrast, writing a name that you have never encountered requires attention to the sequence of letters.

The benefits of attention are particularly salient when we refer to conscious attentional processes. In addition to the overall value of attention, conscious attention serves three purposes in playing a causal role for cognition. First, it helps in monitoring our interactions with the environment. Through such monitoring, we maintain our awareness of how well we are adapting to the situation in which we find ourselves. Second, it assists us in linking our past (memories) and our present (sensations) to give us a sense of continuity of experience. Such continuity may even serve as the basis for personal identity. Third, it helps us in controlling and planning for our future actions. We can do so based on the information from monitoring and from the links between past memories and present sensations.

**Preconscious Processing**

Some information that currently is outside our conscious awareness still may be available to consciousness or at least to cognitive processes. Information that is available for cognitive processing but that currently lies outside conscious awareness exists at the preconscious level of awareness. Preconscious information includes stored memo-
ries that we are not using at a given time but that we could summon when needed. For example, when prompted, you can remember what your bedroom looks like. But obviously you are not always consciously thinking about your bedroom (unless, perhaps, you are extremely tired). Sensations, too, may be pulled from preconscious to conscious awareness. For example, before you read this sentence, were you highly aware of the sensations in your right foot? Probably not. However, those sensations were available to you.

How can we study things that currently lie outside conscious awareness? Psychologists have solved this problem by studying a phenomenon known as priming. **Priming** occurs when recognition of certain stimuli is affected by prior presentation of the same or similar stimuli (Neely, 2003). Suppose, for example, someone is talking to you about how much he has enjoyed watching television since buying a satellite dish. He speaks at length about the virtues of satellite dishes. Later, you hear the word *dish*. You are probably more likely to think of a satellite dish, as opposed to a dish served at dinner, than is someone who did not hear the prior conversation about satellite dishes. Most priming is positive. Prior presentation of stimuli facilitates later recognition. But priming on occasion may be negative. It may impede later recognition. Sometimes we are aware of the priming stimuli. For example, you are now primed to read descriptions of studies involving priming. However, priming occurs even when the priming stimulus is presented in a way that does not permit its entry into conscious awareness. In such a case, it is presented at too low an intensity, in too “noisy” a background (i.e., too many other stimuli divert conscious attention from it), or too briefly to be registered in conscious awareness.

For example, in a set of studies Marcel observed processing of stimuli that were presented too briefly to be detected in conscious awareness (Marcel, 1983a, 1983b). In these studies, words were presented to participants very briefly (as measured in milliseconds, or thousandths of a second). After presentation, each word was replaced by a visual mask. The mask blocks the image of the word from remaining on the retina (the rear surface of the eye, comprising the sensory receptors of vision). Marcel timed the presentations to be very brief (20–110 milliseconds). In this way, he was sure that participants could not detect their presence consciously. When participants were asked to guess the word they had seen, their guesses were no better than chance.

In one such study, Marcel presented participants with a series of words to be classified into various categories. Examples would be *leg—body part* and *pine—plant*. In this study, the priming stimuli were words having more than one meaning. For example, a palm can be either a tree or a part of the hand. In one condition, participants consciously were aware of seeing a priming word that had two meanings. For these participants, the mental pathway for only one of the two meanings seemed to become activated. In other words, one of the two meanings of the word showed the priming effect. It facilitated (speeded up) the classification of a subsequent related word. However, the other of the two meanings showed a sort of negative priming effect. It actually inhibited (slowed down) the classification of a subsequent unrelated word. For example, if the word *palm* was presented long enough so that the participant was consciously aware of seeing it, the word either facilitated or inhibited the classification of the word *wrist*, which it did depending on whether the participant associated *palm* with *hand* or with *tree*. Apparently, if the participant was consciously aware of seeing the word *palm*, the mental pathway for only one meaning was activated. The
mental pathway for the other meaning was inhibited. In contrast, if the word palm was presented so briefly that the person was unaware of seeing the word, both meanings of the word appeared to be activated. This procedure facilitated subsequent classification of the new words, such as wrist.

Marcel’s results were controversial and in need of replication by independent investigators using stringent controls. Such a replication was indeed performed (Cheesman & Merikle, 1984). The investigators used a color-identification task. They found that the occurrence of subliminal perception depended on how one defined the threshold of awareness. If one defined the threshold below which perception is subliminal in terms of the level at which participants report a word occurring half the time, then subliminal perception could be said to occur. If, however, one defined subliminal perception in terms of an objective threshold that applies for everyone, then subliminal perception did not occur. This study points out the importance of a precise definition in any cognitive-psychological investigation. Whether a phenomenon occurs sometimes depends on exactly how that phenomenon is defined.

Another example of possible priming effects and preconscious processing can be found in a study described as a test of intuition. This study used a “dyad of triads” task (Bowers & associates, 1990). Participants were presented with pairs (dyads) of three-word groups (triads). One of the triads in each dyad was a potentially coherent grouping. The other triad contained random and unrelated words. For example, the words in Group A, a coherent triad, might have been playing, credit, and report. The words in Group B, an incoherent triad, might have been still, pages, and music. After presentation of the dyad of triads, participants were shown various possible choices for a fourth word related to one of the two triads. The participants then were asked to identify two things. The first was which of the two triads was coherent and related to a fourth word. The second was which fourth word linked the coherent triad. In the preceding example, the words in Group A can be meaningfully paired with a fourth word—card (playing card, credit card, report card). The words in Group B bear no such relationship.

Some participants could not figure out the unifying fourth word for a given pair of triads. They were nevertheless asked to indicate which of the two triads was coherent. When participants could not ascertain the unifying word, they still were able to identify the coherent triad at a level well above chance. They seemed to have some preconscious information available to them. This information led them to select one triad over the other. They did so even though they did not consciously know what word unified that triad.

The examples described above involve visual priming. Priming, however, does not have to be visual. Priming effects can be demonstrated using aural material as well. Experiments exploring auditory priming reveal the same behavioral effects as visual priming. Using neuroimaging methods, investigators have discovered that similar brain areas are involved in both types of priming (Badgaiyan, Schacter, & Alpert, 1999; Bergerbest, Ghahremani, & Gabrieli, 2004; Schacter & Church, 1992).

An interesting application of auditory priming was used with patients under anesthesia. While under anesthesia, these patients were presented lists of words. After awakening from anesthesia, the patients were asked yes/no questions and word-stem completion questions about the words they heard. The patients performed at chance on the yes/no questions. They reported no conscious knowledge of the words. How-
ever, on the word-stem completion task, patients showed evidence of priming. The patients frequently completed the word-stems with the items they were presented while they were under anesthesia. These findings reveal that, even when the patient has absolutely no recollection of an aural event, it can still affect performance (Dee-prose & associates, 2005).

Unfortunately, sometimes pulling preconscious information into conscious awareness is not easy. For example, most of us have experienced the tip-of-the-tongue phenomenon, in which we try to remember something that is known to be stored in memory but that cannot readily be retrieved. Psychologists have tried to come up with experiments that measure this phenomenon. For example, they have sought to find out how much people can draw from information that seems to be stuck at the preconscious level. In one study (Brown & McNeill, 1966), participants were read a large number of dictionary definitions. They then were asked to identify the corresponding words having these meanings. This procedure constituted a game similar to the television show Jeopardy. For example, they might have been given the clue, “an instrument used by navigators to measure the angle between a heavenly body and a horizon.”

In the study, some participants could not come up with the word but thought they knew it. They then were asked various questions about the word. For example, they might be asked to identify the first letter, indicate the number of syllables, or approximate the word’s sounds. The participants often answered these questions accurately. They might have been able to indicate some properties of the appropriate word for the aforementioned instrument. For example, it begins with an $s$, has two syllables, and sounds like sextet. Eventually, some participants realized that the sought-after word was sextant. These results indicate that particular preconscious information, although not fully accessible to conscious thinking, is still available to attentional processes.

The tip-of-the-tongue phenomenon is apparently universal. It is seen in speakers of many different languages. It is also seen in people with limited or no ability to read (Brennen, Vikan, & Dybdahl, 2007). The tip-of-the-tongue phenomenon is affected by the person’s age and the difficulty of the question. Older adults have more tip-of-the-tongue experiences compared with younger adults (Gollan & Brown, 2006). The anterior cingulate-prefrontal cortices are involved when one is experiencing the tip-of-the-tongue phenomenon. This is likely due to high-level cognitive mechanisms being activated in order to resolve the retrieval failure (Maril, Wagner, & Schacter, 2001).

Preconscious perception also has been observed in people who have lesions in some areas of the visual cortex (Ro & Rafal, 2006). Typically, the patients are blind in areas of the visual field that correspond to the lesioned areas of the cortex. Some of these patients, however, seem to show blindsight—traces of visual perceptual ability in blind areas (Kentridge, 2003). When forced to guess about a stimulus in the “blind” region, they correctly guess locations and orientations of objects at above-chance levels (Weiskrantz, 1994). Similarly, when forced to reach for objects in the blind area, “cortically blind participants . . . will nonetheless preadjust their hands appropriately to size, shape, orientation and 3-D location of that object in the blind field” (Marcel, 1986, p. 41). Yet they fail to show voluntary behavior, such as reaching for a glass of water in the blind region, even when they are thirsty. Some visual processing seems to occur even when participants have no conscious awareness of visual sensations.
An interesting example of blindsight can be found in a case study of a patient called D. B. (Weiskrantz, 1986). The patient was blind on the left side of his visual field as an unfortunate result of an operation. That is, each eye had a blind spot on the left side of its visual field. Consistent with this damage, D. B. reported no awareness of any objects placed on his left side or of any events that took place on this side. But despite his unawareness of vision on this side, there was evidence of vision. The investigator would present objects to the left side of the visual field and then present D. B. with a forced-choice test in which the patient had to indicate which of two objects had been presented to this side. D. B. performed at levels that were significantly better than chance. In other words, he “saw” despite his unawareness of seeing.

Another study was completed on a patient who had, as a result of a stroke, suffered damage to his visual cortex. The experimenters repeatedly paired a visual stimulus with an electric shock. After multiple pairings, the patient began to experience fear when the visual stimulus was presented, even though he could not explain why he was afraid. Thus, the patient was processing visual information, although he could not see (Hamm & associates, 2003).

The preceding examples show that at least some cognitive functions can occur outside of conscious awareness. We appear able to sense, perceive, and even respond to many stimuli that never enter our conscious awareness (Marcel, 1983a). Just what kinds of processes do or do not require conscious awareness?

Repeatedly write your name on a piece of paper while you picture everything you can remember about the room in which you slept when you were 10 years old. While continuing to write your name and picturing your old bedroom, take a mental journey of awareness to notice your bodily sensations, starting from one of your big toes and proceeding up your leg, across your torso, to the opposite shoulder, and down your arm. What sensations do you feel—pressure from the ground, your shoes, or your clothing or even pain anywhere? Are you still managing to write your name while retrieving remembered images from memory and continuing to pay attention to your current sensations?

**Controlled versus Automatic Processes**

Many cognitive processes also may be differentiated in terms of whether they do or do not require conscious control (Schneider & Shiffrin, 1977; Shiffrin & Schneider, 1977). **Automatic processes** involve no conscious control (see Palmeri, 2003). For the most part, they are performed without conscious awareness. Nevertheless, you may be aware that you are performing them. They demand little or no effort or even intention. Multiple automatic processes may occur at once, or at least very quickly, and in no particular sequence. Thus, they are termed parallel processes. In contrast, **controlled processes** are accessible to conscious control and even require it. Such processes are performed serially. In other words, they occur sequentially, one step at a time. They take a relatively long time to execute, at least as compared with automatic processes.

Three attributes characterize automatic processes (Posner & Snyder, 1975). First, they are concealed from consciousness. Second, they are unintentional. Third, they
From this point on, however, our experiments on cognition look just like anyone else’s—except that our subjects are hypnotized. In one study using a familiar verbal-learning paradigm (Kihlstrom, 1980), the subjects memorized a list of 15 familiar words, such as girl or chair, and then received a suggestion for posthypnotic amnesia: “You will not be able to remember that you learned any words while you were hypnotized….You will have no memory that I told you these words, or what the words were.” As part of this suggestion, we set up a “reversibility cue” (“Now you can remember everything”) to cancel the amnesia suggestion. After coming out of hypnosis, highly hypnotizable subjects remembered virtually none of the list, whereas insusceptible subjects, who had gone through the same procedures, remembered the list almost perfectly. This shows that the occurrence of posthypnotic amnesia is highly correlated with hypnotizability.

Then we gave all subjects a word-association test, in which they were presented with cues and asked to report the first word that came to mind. Some of these cues were words like boy and table, which were known to have a high probability of producing the “critical targets” on the study list. Others were control cues, like lamp and dogs, which had an equally high probability of producing neutral targets like light and cats, which had not been studied. Despite their inability to remember the words they had just studied, the hypnotizable, amnesic subjects produced critical rather than neutral targets on the free-association test. This is a phenomenon of semantic priming, in which a previous experience, such as studying a list of words, facilitates performance on a subsequent task, such as generating words on a free-
consume few attentional resources. An alternative view of attention suggests a continuum of processes between fully automatic processes and fully controlled processes. For one thing, the range of controlled processes is so wide and diverse that it would be difficult to characterize all the controlled processes in the same way (Logan, 1988). Similar difficulties arise with characterizing automatic processes. Some automatic processes truly cannot be retrieved into conscious awareness, despite any amount of effort to do so. Examples are preconscious processing and priming. Other automatic processes, such as tying your shoes, can be controlled intentionally. But they rarely are handled in this way. For example, you seldom may think about all the steps involved in executing many automatic behaviors. Automatic behaviors, regardless of whether they can be called into consciousness, require no conscious decisions regarding which muscles to move or which actions to take. For example, when you dial a familiar telephone number or drive a car to a familiar place, you do not think about

References
the muscles you move to do so. However, their identities can be pulled into conscious awareness and controlled relatively easily. (Table 4.1 summarizes the characteristics of controlled versus automatic processes.)

In fact, many tasks that start off as controlled processes eventually become automatic ones. For example, driving a car is initially a controlled process. Once we master driving, however, it becomes automatic under normal driving conditions. Such conditions involve familiar roads, fair weather, and little or no traffic. Similarly, when you first learn to speak a foreign language, you need to translate word-for-word from your native tongue. Eventually, however, you begin to think in the second language. This thinking enables you to bypass the intermediate-translation stage. It also allows the process of speaking to become automatic. Your conscious attention can revert to the content, rather than the process, of speaking. A similar shift from conscious control to automatic processing occurs when acquiring the skill of reading.

**TABLE 4.1** Controlled versus Automatic Processes

<table>
<thead>
<tr>
<th>CHARACTERISTICS</th>
<th>CONTROLLED PROCESSES</th>
<th>AUTOMATIC PROCESSES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amount of intentional effort</td>
<td>Require intentional effort</td>
<td>Require little or no intention or effort (and intentional effort may even be required to avoid automatic behaviors)</td>
</tr>
<tr>
<td>Degree of conscious awareness</td>
<td>Require full conscious awareness</td>
<td>Generally occur outside of conscious awareness, although some automatic processes may be available to consciousness</td>
</tr>
<tr>
<td>Use of attentional resources</td>
<td>Consume many attentional resources</td>
<td>Consume negligible attentional resources</td>
</tr>
<tr>
<td>Type of processing</td>
<td>Performed serially (one step at a time)</td>
<td>Performed by parallel processing (i.e., with many operations occurring simultaneously or at least in no particular sequential order)</td>
</tr>
<tr>
<td>Speed of processing</td>
<td>Relatively time-consuming execution, as compared with automatic processes</td>
<td>Relatively fast</td>
</tr>
<tr>
<td>Relative novelty of tasks</td>
<td>Novel and unpracticed tasks or tasks with many variable features</td>
<td>Familiar and highly practiced tasks, with largely stable task characteristics</td>
</tr>
<tr>
<td>Level of processing</td>
<td>Relatively high levels of cognitive processing (requiring analysis or synthesis)</td>
<td>Relatively low levels of cognitive processing (minimal analysis or synthesis)</td>
</tr>
<tr>
<td>Difficulty of tasks</td>
<td>Usually difficult tasks</td>
<td>Usually relatively easy tasks, but even relatively complex tasks may be automatized, given sufficient practice</td>
</tr>
<tr>
<td>Process of acquisition</td>
<td>With sufficient practice, many routine and relatively stable procedures may become automatized, such that highly controlled processes may become partly or even wholly automatic; naturally, the amount of practice required for automatization increases dramatically for highly complex tasks</td>
<td></td>
</tr>
</tbody>
</table>
However, when conditions change, the same activity may again require conscious control. In the driving example, if the roads become icy, you will likely need to pay attention to when you need to brake or accelerate. Both tasks usually are automatic when driving.

You may notice that the procedures you learned early in life often are more highly automatic and less accessible to conscious awareness than are procedures acquired later. Examples are tying your shoes, riding a bicycle, or even reading. In general, more recently acquired routine processes and procedures are less fully automatic. At the same time, they are more accessible to conscious control. **Automatization** (also termed *proceduralization*) is the process by which a procedure changes from being highly conscious to being relatively automatic. As you may have guessed based on your own experience, automatization occurs as a result of practice. Highly practiced activities can be automatized (LaBerge, 1975, 1976, 1990; LaBerge & Samuels, 1974).

How does automatization occur? A widely accepted view has been that during the course of practice, implementation of the various steps becomes more efficient. The individual gradually combines individual effortful steps into integrated components. These components then are further integrated. Eventually the entire process is a single highly integrated procedure, rather than an assemblage of individual steps (Anderson, 1983; LaBerge & Samuels, 1974). According to this view, people consolidate various discrete steps into a single operation. This operation requires few or no cognitive resources, such as attention. This view of automatization seems to be supported by one of the earliest studies of automatization (Bryan & Harter, 1899). This study investigated how telegraph operators gradually automatized the task of sending and receiving messages. Initially, new operators automatized the transmission of individual letters. However, once the operators had made the transmission of letters automatic, they automatized the transmission of words, phrases, and then other groups of words.

An alternative explanation, called “instance theory,” has been proposed. Logan (1988) suggested that automatization occurs because we gradually accumulate knowledge about specific responses to specific stimuli. For example, when a child first learns to add or subtract, he or she applies a general procedure—counting—for handling each pair of numbers. Following repeated practice, the child gradually stores knowledge about particular pairs of particular numbers. Eventually, the child can retrieve from memory the specific answers to specific combinations of numbers. Nevertheless, he or she still can fall back on the general procedure (counting) as needed. Similarly, when learning to drive, the person can draw on an accumulated wealth of specific experiences. These experiences form a knowledge base from which the person quickly can retrieve specific procedures for responding to specific stimuli, such as oncoming cars or stoplights. Preliminary findings suggest that Logan’s instance theory may better explain specific responses to specific stimuli, such as calculating arithmetic combinations. The prevailing view may better explain more general responses involving automatization (Logan, 1988).

The effects of practice on automatization show a negatively accelerated curve. In such a curve, early practice effects are great. A graph of improvement in performance would show a steeply rising curve early on. Later practice effects make less and less difference in the degree of automatization. On a graph showing improvement, the curve would eventually level off (Figure 4.2). Clearly, automatic processes generally
govern familiar, well-practiced tasks. Controlled processes govern relatively novel tasks. In addition, most automatic processes govern relatively easy tasks. Most difficult tasks require controlled processing. With sufficient practice, however, even many extremely complex tasks, such as reading, can become automatized. Because highly automatized behaviors require little effort or conscious control, we often can engage in multiple automatic behaviors. But we rarely can engage in more than one labor-intensive controlled behavior. Although automatic processes do not require conscious control, they are subject to such control. For example, skilled articulation (speaking) and skilled typing can be stopped almost immediately on signal or in response to detection of an error. However, skilled performance of automatic behaviors often is impaired by conscious control. Try riding a bicycle while consciously monitoring your every movement. It will be extremely difficult to succeed.

Automatization of tasks like reading is not guaranteed, even with practice. Much research has indicated that, in cases of dyslexia, automatization is impaired. More specifically, persons who have dyslexia frequently have difficulty completing tasks, in addition to reading, that are normally automated (Brambati & associates, 2006; Ramus & associates, 2003; van der Leij, de Jong, & Rijswijk-Prins, 2001; Yap & van der Leij, 1994). It is not necessary that all tasks that involve automatization are impaired in people with dyslexia. In some studies, some degree of automatization has been noted in persons with dyslexia (Kelly, Griffths, & Frith, 2002).
It is important to automate various safety practices (Norman, 1976). This is particularly true for people engaging in high-risk occupations, such as pilots, undersea divers, and firefighters. For example, novice divers often complain about the frequent repetition of various safety procedures within the confines of a swimming pool. An example would be releasing a cumbersome weight belt. However, the practice is important, as the novices will learn later. Experienced divers recognize the value of being able to rely on automatic processes in the face of potential panic should they confront a life-threatening deep-sea emergency.

In some situations, automatic processes may be life saving. But in others, they may be life threatening (Langer, 1997). Consider an example of what Langer (1989) calls “mindlessness.” In 1982, a pilot and copilot went through a routine checklist prior to takeoff. They mindlessly noted that the anti-icer was “off,” as it should be under most circumstances. But it should not have been off under the icy conditions in which they were preparing to fly. The flight ended in a crash that killed 74 passengers. Typically, our absentminded implementation of automatic processes has far less lethal consequences. For example, when driving, we may end up routinely driving home instead of stopping by the store, as we had intended to do. Or we may pour a glass of milk and then start to put the carton of milk in the cupboard rather than in the refrigerator.

An extensive analysis of human error notes that errors can be classified either as mistakes or as slips (Reason, 1990). Mistakes are errors in choosing an objective or in specifying a means of achieving it. Slips are errors in carrying out an intended means for reaching an objective. Suppose, for example, you decided that you did not need to study for an examination. Thus, you purposely left your textbook behind when leaving for a long weekend. But then you discovered at the time of the exam that you should have studied. In Reason’s terms, you made a mistake. However, suppose instead you fully intended to bring your textbook with you. You had planned to study extensively over the long weekend, but in your haste to leave, you accidentally left the textbook behind. That would be a slip. In sum, mistakes involve errors in intentional, controlled processes. Slips often involve errors in automatic processes (Reason, 1990).

There are several kinds of slips (Norman, 1988; Reason, 1990; see Table 4.2). In general, slips are most likely to occur when two circumstances occur. First, when we must deviate from a routine and automatic processes inappropriately override intentional, controlled processes. Second, when our automatic processes are interrupted. Such interruptions are usually a result of external events or data, but sometimes they are a result of internal events, such as highly distracting thoughts. Imagine that you are typing a paper after an argument with a friend. You may find yourself pausing in your typing as thoughts about what you should have said interrupt your normally automatic process of typing. Automatic processes are helpful to us under many circumstances. They save us from needlessly focusing attention on routine tasks, such as tying our shoes or dialing a familiar phone number. We are thus unlikely to forgo them just to avoid occasional slips. Instead, we should attempt to minimize the costs of these slips.

How can we minimize the potential for negative consequences of slips? In everyday situations, we are less likely to slip when we receive appropriate feedback from the environment. For example, the milk carton may be too tall for the cupboard shelf, or a passenger may say, “I thought you were stopping at the store before going home.”
If we can find ways to obtain useful feedback, we may be able to reduce the likelihood that harmful consequences will result from slips. A particularly helpful kind of feedback involves forcing function. These are physical constraints that make it difficult or impossible to carry out an automatic behavior that may lead to a slip (Norman, 1988). As an example of a forcing function, some modern cars make it difficult or impossible to carry out an automatic behavior that may lead to a slip (Norman, 1988).

### TABLE 4.2 Slips Associated with Automatic Processes

Occasionally, when we are distracted or interrupted during implementation of an automatic process, slips occur. However, in proportion to the number of times we engage in automatic processes each day, slips are relatively rare events (Reason, 1990).

<table>
<thead>
<tr>
<th>Type of Error</th>
<th>Description of Error</th>
<th>Example of Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capture errors</td>
<td>We intend to deviate from a routine activity we are implementing in familiar surroundings, but at a point where we should depart from the routine we fail to pay attention and to regain control of the process; hence, the automatic process captures our behavior, and we fail to deviate from the routine.</td>
<td>Psychologist William James (1890/1970, cited in Langer, 1989) gave an example in which he automatically followed his usual routine, undressing from his work clothes, then putting on his pajamas and climbing into bed—only to realize that he had intended to remove his work clothes to dress to go out to dinner.</td>
</tr>
<tr>
<td>Omissions*</td>
<td>An interruption of a routine activity may cause us to skip a step or two in implementing the remaining portion of the routine.</td>
<td>When going to another room to retrieve something, if a distraction (e.g., a phone call) interrupts you, you may return to the first room without having retrieved the item.</td>
</tr>
<tr>
<td>Perseverations*</td>
<td>After an automatic procedure has been completed, one or more steps of the procedure may be repeated.</td>
<td>If, after starting a car, you become distracted, you may turn the ignition switch again.</td>
</tr>
<tr>
<td>Description errors</td>
<td>An internal description of the intended behavior leads to performing the correct action on the wrong object.</td>
<td>When putting away groceries, you may end up putting the ice cream in the cupboard and a can of soup in the freezer.</td>
</tr>
<tr>
<td>Data-driven errors</td>
<td>Incoming sensory information may end up overriding the intended variables in an automatic action sequence.</td>
<td>While intending to dial a familiar phone number, if you overhear someone call out another series of numbers, you may end up dialing some of those numbers instead of the ones you intended to dial.</td>
</tr>
<tr>
<td>Associative-</td>
<td>Strong associations may trigger the wrong automatic routine.</td>
<td>When expecting someone to arrive at the door, if the phone rings, you may call out, “Come in!”</td>
</tr>
<tr>
<td>activation errors</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Loss-of-activation</td>
<td>The activation of a routine may be insufficient to carry it through to completion.</td>
<td>All too often, each of us has experienced the feeling of going to another room to do something and getting there only to ask ourselves, “What am I doing here?” Perhaps even worse is the nagging feeling, “I know I should be doing something, but I can't remember what.” Until something in the environment triggers our recollection, we may feel extremely frustrated.</td>
</tr>
</tbody>
</table>

*Omissions and perseverations may be considered examples of errors in the sequencing of automatic processes. Related errors include inappropriately sequencing the steps, as in trying to remove socks before taking off shoes.
impossible to drive the car without wearing a seatbelt. You can devise your own forcing functions. You may post a small sign on your steering wheel as a reminder to run an errand on the way home. Or you may put items in front of the door. In this way, you block your exit so that you cannot leave without the items you want.

Over a lifetime, we automatize countless everyday tasks. However, one of the most helpful pairs of automatic processes first appears within hours after birth: habituation and its complementary opposite, dishabituation.

**Habituation and Adaptation**

**Habituation** involves our becoming accustomed to a stimulus so that we gradually pay less and less attention to it. The counterpart to habituation is dishabituation. In **dishabituation**, a change in a familiar stimulus prompts us to start noticing the stimulus again. Both processes occur automatically. They involve no conscious effort. The relative stability and familiarity of the stimulus govern these processes. Any aspects of the stimulus that seem different or novel (unfamiliar) either prompt dishabituation or make habituation less likely to occur in the first place. For example, suppose that a radio is playing instrumental music while you study your cognitive psychology textbook. At first the sound might distract you. But after a while you become habituated to the sound and scarcely notice it. If the loudness of the noise were suddenly to change drastically, however, immediately you would dishabituate to it. The once familiar sound to which you had been habituated would become unfamiliar. It thus

Habituation is not without faults. Becoming bored during a lecture or while reading a textbook is a sign of habituation. Your attention may start to wander to the background noises, or you may find that you have read a paragraph or two with no recollection of the content. Fortunately, you can dishabituate yourself with very little effort. Here are a few tips on how to overcome the negative effects of boredom.

1. Take a break or alternate between different tasks if possible. If you do not remember the last few paragraphs of the text, it is time to stop for a few minutes. Go back and mark the last place in the text you do remember and put the book down. If you feel like a break is a waste of valuable time, do some other work for a while.

2. Take notes while reading or listening. Most people already do so. Note-taking focuses attention on the material more than does simply listening or reading. If necessary, try switching from script to printed handwriting to make the task more interesting.

3. Adjust your attentional focus to increase stimulus variability. Is the instructor’s voice droning on endlessly so that you cannot take a break during lecture? Try noticing other aspects of your instructor, like hand gestures or body movements, while still paying attention to the content. Create a break in the flow by asking a question—even just raising your hand can make a change in a lecturer’s speaking pattern. Change your arousal level. If all else fails, you may have to force yourself to be interested in the material. Think about how you can use the material in your everyday life. Also, sometimes just taking a few deep breaths or closing your eyes for a few seconds can change your internal arousal levels.
would enter your awareness. Habituation is not limited to humans. It is found in organisms as simple as the mollusk *Aplysia* (Castellucci & Kandel, 1976).

We usually exert no effort whatsoever to become habituated to our sensations of stimuli in the environment. Nonetheless, although we usually do not consciously control habituation, we can do so. In this way, habituation is an attentional phenomenon that differs from the physiological phenomenon of sensory adaptation. **Sensory adaptation** is a lessening of attention to a stimulus that is not subject to conscious control. It occurs directly in the sense organ, not in the brain. We can exert some conscious control over whether we notice something to which we have become habituated, but we have no conscious control over sensory adaptation. For example, we cannot consciously force ourselves to smell an odor to which our senses have become adapted. Nor can we consciously force our pupils to adapt—or not adapt—to differing degrees of brightness or darkness. In contrast, if someone asked us, “Who’s the lead guitarist in that song?” we can once again notice background music. Table 4.3 provides some of the other distinctions between sensory adaptation and habituation.

Two factors that influence habituation are stimulus internal variation and subjective arousal. Some stimuli involve more internal variation than do others. For example, background music contains more internal variation than does the steady drone of an air conditioner. The relative complexity of the stimulus (e.g., an ornate, intricate Oriental rug versus a gray carpet) does not seem to be important to habituation. Rather, what matters is the amount of change within the stimulus over time. For example, a mobile involves more change than does an ornate but rigid sculpture. Thus, it is relatively difficult to remain continually habituated to the frequently changing noises coming from a television. But it is relatively easy to become habituated to a constantly running fan. The reason is that the voices typically speak anima-

### Table 4.3 Differences between Sensory Adaptation and Habituation

<table>
<thead>
<tr>
<th><strong>Adaptation</strong></th>
<th><strong>Habituation</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Not accessible to conscious control (Example: You cannot decide how quickly to adapt to a particular smell or a particular change in light intensity.)</td>
<td>Accessible to conscious control (Example: You can decide to become aware of background conversations to which you had become habituated.)</td>
</tr>
<tr>
<td>Tied closely to stimulus intensity (Example: The more the intensity of a bright light increases, the more strongly your senses will adapt to the light.)</td>
<td>Not tied very closely to stimulus intensity (Example: Your level of habituation will not differ much in your response to the sound of a loud fan and to that of a quiet air conditioner.)</td>
</tr>
<tr>
<td>Unrelated to the number, length, and recency of prior exposures (Example: The sense receptors in your skin will respond to changes in temperature in basically the same way no matter how many times you have been exposed to such changes and no matter how recently you have experienced such changes.)</td>
<td>Tied very closely to the number, length, and recency of prior exposures (Example: You will become more quickly habituated to the sound of a chiming clock when you have been exposed to the sound more often, for longer times, and on more recent occasions.)</td>
</tr>
</tbody>
</table>
tedly and with great inflectional expression. They are constantly changing, whereas the sound a fan makes remains constant with little to no variation.

Psychologists can observe habituation occurring at the physiological level by measuring our degree of arousal. **Arousal** is a degree of physiological excitation, responsivity, and readiness for action, relative to a baseline. Arousal often is measured in terms of heart rate, blood pressure, electroencephalograph (EEG) patterns, and other physiological signs. Consider what happens, for example, when an unchanging visual stimulus remains in our visual field for a long time. Our neural activity (as shown on an EEG) in response to that stimulus decreases (see Chapter 2). Both neural activity and other physiological responses (e.g., heart rate) can be measured. These measurements detect heightened arousal in response to perceived novelty or diminished arousal in response to perceived familiarity. In fact, psychologists in many fields use physiological indications of habituation to study a wide array of psychological phenomena in people who cannot provide verbal reports of their responses. Examples of such people are infants and comatose patients. Physiological indicators of habituation tell the researcher whether the person notices changes in the stimulus. Such changes might occur in the color, pattern, size, or form of a stimulus. These indicators signal whether the person notices the changes at all, as well as what specific changes the person notices in the stimulus.

Among other phenomena, psychologists have used habituation to study visual discrimination (detection of differences among stimuli) in infants. First, they habituate the infant to a particular visual pattern. They do so by presenting it until the infant no longer pays attention to it. Then they introduce a visual pattern that only slightly differs from the one to which the infant has become habituated. If the infant is able to discriminate the difference, the infant will not habituate to (i.e., will notice) the new pattern. If the infant cannot discriminate the difference, however, the infant will appear to be habituated to the new pattern as well.

Habituation definitely gives much more to our attentional system than it receives. That is, habituation itself requires no conscious effort and few attentional resources. Despite its negligible use of attentional resources, it offers a great deal of support to attentional processes. It allows us easily to turn our attention away from familiar and relatively stable stimuli and toward novel and changing stimuli. We might conjecture about the evolutionary value of habituation. Without habituation, our attentional system would be much more greatly taxed. How easily would we function in our highly stimulating environments if we could not habituate to familiar stimuli? Imagine trying to listen to a lecture if you could not habituate to the sounds of your own breathing, the rustling of papers and books, or the faint buzzing of fluorescent lights.

An example of the failure to habituate can be seen in persons who suffer from tinnitus. Tinnitus is a ringing in the ears. People who complain of having tinnitus seem to have problems habituating to auditory stimuli. Many people have ringing in their ears, and if they are placed in a quiet room, will report a buzzing or other sounds. However, people who chronically suffer from tinnitus have difficulty adapting to the noise (Walpurger & associates, 2003). Evidence also indicates that people with attention deficit hyperactivity disorder (ADHD), which will be discussed later in this chapter, have difficulty habituating to many types of stimuli. This difficulty helps to explain why ordinary stimuli, such as the buzzing of fluorescent lights, can be distracting to a person with ADHD (Jansiewicz & associates, 2004).
**Signal Detection**

Habituation supports our attentional system, but this system performs many functions other than merely tuning out familiar stimuli and tuning into novel ones. Conscious attention has four main functions. First, in **signal detection**, we detect the appearance of a particular stimulus. We try to detect a signal, through vigilance, even after we begin to feel fatigue as a result of long-term absence of a signal. Second, in **selective attention**, we choose to attend to some stimuli and to ignore others (Cohen, 2003; Duncan, 1999). Third, in **divided attention**, we prudently allocate our available attentional resources to coordinate our performance of more than one task at a time. Fourth, in search, we try to find a signal amidst distractors. These four functions are summarized in Table 4.4.

First consider signal detection. What factors contribute to your ability to detect important events in the world? How do people search the environment to detect important stimuli? Understanding this function of attention has immediate practical importance. A lifeguard at a busy beach must be ever vigilant. Similarly, an air-traffic controller must be highly vigilant. Many other occupations require vigilance. Examples are those involving communications and warning systems and quality control in almost any setting. Even the work of police detectives, physicians, and research psychologists requires vigilance. We also must search out from among a diverse array of items those that are more important. In each of these settings, people must remain alert to detect the appearance of a stimulus. But each setting also involves the presence of distracters, as well as prolonged periods during which the stimulus is absent.

**The Nature of Signal Detection**

Signal-detection theory (SDT) involves four possible outcomes of the presence or absence of a stimulus and our detection or nondetection of a stimulus. It characterizes our attempts to detect a **signal**, a target stimulus (Table 4.5). First, in **hits** (also called “true positives”), we correctly identify the presence of a target. Second, in **false alarms** (also called “false positives”), we incorrectly identify the presence of a target that is actually absent. Third, in **misses** (also called “false negatives”), we fail to observe the presence of a target. Fourth, in **correct rejections** (also called “true negatives”), we correctly identify the absence of a target. Usually, the presence of a target is difficult to detect. Thus, we make detection judgments based on inconclusive information with some criteria for target detections. The number of hits is influenced by where you place your criteria for considering something a hit. In other words, how willing are you to make false alarms? For example, sometimes the consequences of making a miss are so grave that we lower the criteria for considering something as a hit. In this way, we increase the number of false alarms we make to boost hit detection. This trade-off often occurs with medical diagnoses. For example, it might occur with highly sensitive screening tests where positive results lead to further tests. Thus, overall sensitivity to targets must reflect the placement of a flexible criterion and is measured in terms of hits minus false alarms. SDT often is used to measure sensitivity to a target’s
Cognitive psychologists have been particularly interested in the study of divided attention, vigilance and signal detection, search, and selective attention.

<table>
<thead>
<tr>
<th><strong>FUNCTION</strong></th>
<th><strong>DESCRIPTION</strong></th>
<th><strong>EXAMPLE</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Vigilance and signal detection</td>
<td>On many occasions, we vigilantly try to detect whether we did or did not sense a signal, a particular target stimulus of interest. Through vigilant attention to detecting signals, we are primed to take speedy action when we do detect signal stimuli.</td>
<td>In a research submarine, we may watch for unusual sonar blips; in a dark street, we may try to detect unwelcome sights or sounds; or following an earthquake, we may be wary of the smell of leaking gas or of smoke.</td>
</tr>
<tr>
<td>Selective attention</td>
<td>We constantly are making choices regarding the stimuli to which we will pay attention and the stimuli that we will ignore. By ignoring or at least deemphasizing some stimuli, we thereby highlight particularly salient stimuli. The concentrated focus of attention on particular informational stimuli enhances our ability to manipulate those stimuli for other cognitive processes, such as verbal comprehension or problem solving.</td>
<td>We may pay attention to reading a textbook or to listening to a lecture while ignoring such stimuli as a nearby radio or television or latecomers to the lecture.</td>
</tr>
<tr>
<td>Divided attention</td>
<td>We often manage to engage in more than one task at a time, and we shift our attentional resources to allocate them prudently, as needed.</td>
<td>Experienced drivers easily can talk while driving under most circumstances, but if another vehicle seems to be swerving toward their car, they quickly switch all their attention away from talking and toward driving.</td>
</tr>
<tr>
<td>Search</td>
<td>We often engage in an active search for particular stimuli.</td>
<td>If we detect smoke (as a result of our vigilance), we may engage in an active search for the source of the smoke. In addition, some of us are constantly in search of missing keys, sunglasses, and other objects; my son often “searches” for missing items in the refrigerator (often without much success—until someone else points them out to him).</td>
</tr>
</tbody>
</table>

**TABLE 4.5**  Signal Detection Matrix Used in Signal-Detection Theory

Signal-detection theory was one of the first theories to suggest an interaction between the physical sensation of a stimulus and cognitive processes such as decision making.

<table>
<thead>
<tr>
<th><strong>SIGNAL</strong></th>
<th><strong>DETECT A SIGNAL</strong></th>
<th><strong>DO NOT DETECT A SIGNAL</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Present</td>
<td>Hit</td>
<td>Miss</td>
</tr>
<tr>
<td>Absent</td>
<td>False alarm</td>
<td>Correct rejection</td>
</tr>
</tbody>
</table>
Measurement can occur under conditions of both vigilance and the search for targets. It also is used in memory research to control for effects of guessing.

Signal-detection theory can be covered in the context of attention, perception, or memory. It is relevant in the context of attention in terms of whether one is paying enough attention to perceive objects that are there. It is relevant in the context of perception in terms of whether one is able to perceive faint signals that may or may not be beyond one’s perceptual range (such as a very high-pitched tone). It is relevant in the context of memory in terms of whether one indicates one has or has not been exposed to a stimulus before, such as a word that may or may not have appeared on a list that was to be memorized.

Consider a practical example of signal-detection theory relevant to attention—detecting a box cutter in hand-carried luggage. Airport screeners generally are capable of perceiving such objects. The question is whether they attend carefully enough. A hit would involve recognizing a box cutter in a passenger’s luggage. A miss would involve failing to see a box cutter that is there. A false alarm would involve thinking one sees a box cutter when there is none, and a correct rejection would be recognizing that there is no box cutter when there is none.

In a disturbing finding, on September 11, 2001, the 9/11 hijackers were screened at airports as they prepared to board their flights, and several of them were pulled aside because they set off metal detectors. After further screening, they were let onto their planes anyway, although they were carrying box cutters. The results of what constituted a “miss” for the screeners were disastrous. As a result of this fiasco, the rules for screening were tightened up considerably. But the tightening of rules created many false alarms. Babies, grandmothers, and other relatively low-risk passengers started to get second and sometimes even third screenings. So the rules were modified to profile passengers by computer. For example, those who bought one-way tickets or changed their flight plans at the last moment became more likely to be subjected to extra screening. This procedure, in turn, has inconvenienced those travelers who need to change their travel plans frequently, such as business travelers. The system for screening passengers is constantly evolving in order to minimize both misses and false alarms (Figure 4.3).

**Vigilance**

**Vigilance** refers to a person’s ability to attend to a field of stimulation over a prolonged period, during which the person seeks to detect the appearance of a particular target stimulus of interest. When being vigilant, the individual watchfully waits to detect a signal stimulus that may appear at an unknown time. Typically, vigilance is needed in settings where a given stimulus occurs only rarely but requires immediate attention as soon as it does occur. Military officers watching for a sneak attack are engaged in a high-stakes vigilance task.

In one study, participants watched a visual display that looked like the face of a clock (Mackworth, 1948). A clock hand moved in continuous steps. Every once in a while, the clock hand would take a double step. The participants’ task was to press a button as soon as possible after observing a double step. Participants’ performance began to deteriorate substantially after just half an hour of observation. Indeed, after a half hour, participants were missing close to one fourth of the double steps. It ap-
pears that decreases in vigilance are not primarily a result of participants’ decreased sensitivity. Rather, they are due to their increased doubtfulness about their perceived observations (Broadbent & Gregory, 1965). To relate these findings to SDT, over time it appears that participants become less willing to risk reporting false alarms. They err instead by failing to report the presence of the signal stimulus when they are not sure they detect it. They thereby show higher rates of misses. Training can help to increase vigilance (Fisk & Schneider, 1981). But in tasks requiring sustained vigilance, fatigue hinders performance. So there may be no substitute for frequent rest periods to enhance signal detection.

Attentional processes governing signal detection also appear to be highly localized and strongly influenced by expectation (Motter, 1999; Posner, Snyder, & Davidson, 1980). Neurological studies show that signal detection of a visual stimulus is greatest at the point where a signal is expected to appear. Accuracy of signal detection

FIGURE 4.3

Screening hand luggage is an example of signal-detection theory at work in everyday life. Screeners learn techniques to enable them to maximize “hits” and “correct rejections” and to minimize “false alarms” and “misses.”
falls off sharply as the appearance of the stimulus occurs farther from the locus of attention (LaBerge & Brown, 1989; LaBerge, Carter, & Brown, 1992; Mangun & Hilliard, 1990, 1991). Thus, a busy lifeguard or air-traffic controller may respond quickly to a signal within a narrow radius of where a signal is expected to appear. But signals appearing outside the concentrated range of vigilant attention may not be detected as quickly or as accurately.

In vigilance tasks, expectations regarding location strongly affect response efficiency. In this case, efficiency involves the speed and accuracy of detecting a target stimulus. However, expectations regarding the form of the stimulus do not (Posner, Snyder, & Davidson, 1980). Here, form refers to what shape or letter may appear in a visual field. Suppose, now, that a participant is cued to look for a target stimulus in two distant locations. This cueing does not enhance vigilance performance for both locations. Various studies suggest that visual attention may be (very roughly) likened to a spotlight. Stimuli within the region of the attentional spotlight are detected readily, but stimuli outside the spotlight are not detected as well (Eckstein, Shumozaki, & Abbey, 2000; Norman, 1968; Palmer, 1990; Posner, Snyder, & Davidson, 1980). Furthermore, like a spotlight, the beam of focused attention can be narrowly concentrated on a small area or widened to embrace a larger, more diffuse area (Palmer, 1990). However, the abrupt onset of a stimulus (i.e., the sudden appearance of a stimulus) captures our attention. This effect occurs even when factors such as degree of illuminance (brightness) are controlled (Yantis, 1993). Thus, we seem to be predisposed to notice the sudden appearance of stimuli in our visual field. We might speculate about the adaptive advantage this feature of attention may have offered to

For some jobs, vigilance is a matter of life and death.
our ancestral hunter-gatherer forebears. They presumably needed to avoid various predators. They also had to catch various prey.

Increased vigilance is seen in cases where emotional stimuli are used. The amygdala plays a pivotal role in the recognition of emotional stimuli. Thus, the amygdala appears to be an important brain structure in the regulation of vigilance (Phelps, 2004, 2006; Whalen, 1998).

Vigilance is extremely important in warding off terrorist attacks of various kinds. For example, repeating announcements at airports often ask travelers to be vigilant in looking for unattended baggage, which may contain explosives. Because luggage is such a common site at airports, it is difficult to spot bags that are lying unattended, not seeming to belong to anyone. Similarly, in many countries, pedestrians are asked to be vigilant for cars or trucks that seem to be unattended and parked in odd places because they may contain explosives that can be detonated at a distance. The costs of failure of vigilance, in today's world, can be great loss of life as well as property.

**Search**

Whereas vigilance involves passively waiting for a signal stimulus to appear, search involves actively and often skillfully seeking out a target (Pashler, 1998; Posner & DiGirolamo, 1998; Posner, DiGirolamo, & Fernandez-Duque, 1997; Wolfe, 1994). Specifically, search refers to a scan of the environment for particular features—actively looking for something when you are not sure where it will appear. Trying to locate a particular brand of cereal in a crowded aisle at the grocery store—or a particular key term in a crowded textbook—is an example of search. As with vigilance, when we are searching for something, we may respond by making false alarms. Airport screeners look at X-rays of hand luggage, trying to determine whether there are any sharp objects in the baggage that might pose a danger in flight. Search is made more difficult by *distracters*, nontarget stimuli that divert our attention away from the target stimulus. In the case of search, false alarms usually arise when we encounter such distracters while searching for the target stimulus. For instance, consider searching for a product in the grocery store. We often see several distracting items that look something like the item we hope to find. Package designers take advantage of the effectiveness of distracters when creating packaging for products. For example, if a container looks like a box of Cheerios, you may pick it up without realizing that it’s really Tastee-Oh’s.

As you may have expected, the number of targets and distracters affects the difficulty of the task. For example, try to find the $T$ in panel $a$ of Figure 4.4. Then try to find the $T$ in panel $b$ of Figure 4.4. *Display size* is the number of items in a given visual array. (It does not refer to the size of the items or even the size of the field on which the array is displayed.) The display-size effect is the degree to which the number of items in a display hinders (slows down) the search process. When studying visual-search phenomena, investigators often manipulate the display size. They then observe how various contributing factors increase or decrease the display-size effect.

Distracters cause more trouble under some conditions than under others. Suppose we look for some distinctive features. Examples might be color, size, proximity to like items, distance from unlike items, or orientation, such as vertical, horizontal, or oblique. We are able to conduct a *feature search*, in which we simply scan the envi-
Distracters play little role in slowing our search in that case. For example, try to find the O in panel c of Figure 4.4. The O has some distinctive features, as compared with the L distracters in the display. The O thus seems to pop out of the display. Featural singletons, which are items with distinctive features, stand out in the display (Yantis, 1993). When featural singletons are targets, they seem to grab our attention. They make search virtually impossible to avoid. Unfortunately, any featural singletons grab our attention. This includes featural singletons that are distracters. When we are searching for a featural-singleton target stimulus, a featural-singleton distracter stimulus seems to distract us from finding the target (Theeuwes, 1992). For example, find the T in panel d of Figure 4.4. The T is a featural singleton. But the presence of the black (filled) circle probably slows you down in your search.

A problem arises, however, when the target stimulus has no unique or even distinctive features. An example might be a particular boxed or canned item in a grocery aisle. In these situations, the only way we can find it is to conduct a conjunction search (Treisman, 1991). In a conjunction search, we look for a particular combination (conjunction—joining together) of features. For example, the only difference between a T and an L is the particular integration (conjunction) of the line segments. The difference is not a property of any single distinctive feature of either letter. Both letters comprise a horizontal line and a vertical line. So a search looking for either of these features would provide no distinguishing information. In Figure 4.4 a, you had to perform a conjunction search to find the T. So it probably took you longer to find it than to find the O in Figure 4.4 b.

Anne Treisman is a professor of psychology at Princeton University. She is well known for her work in a variety of areas of attention and perception, especially her theory that incoming signals are attenuated rather than filtered when they make their way through the cognitive-processing system.
As we age, our ability to perform an efficient visual search declines. Researchers have noted that this decline is associated with areas that are responsible for processing visual information (Madden & associates, 2007). These findings highlight the importance of the visual system in search.

**Feature-Integration Theory**

According to Anne Treisman, feature-integration theory explains the relative ease of conducting feature searches and the relative difficulty of conducting conjunction searches. Consider Treisman’s (1986) model of how our minds conduct visual searches. For each possible feature of a stimulus, each of us has a mental map for representing the given feature across the visual field. For example, there is a map for every color, size, shape, or orientation (e.g., p, q, b, d) of each stimulus in our visual field. For every stimulus, the features are represented in the feature maps immediately. There is no added time required for additional cognitive processing. Thus, during feature searches, we monitor the relevant feature map for the presence of any activation anywhere in the visual field. This process can be done in parallel (all at once). It therefore shows no display-size effects. However, during conjunction searches, an additional stage of processing is needed. During this stage, we must use our attentional resources as a sort of mental “glue.” It conjoins two or more features into an object representation at a particular location. This attentional process can only conjoin the features one object at a time. This stage must be carried out sequentially, conjoining each object one by one. Effects of display size (i.e., a larger number of objects with features to be conjoined) therefore appear.

*In panel c, find the O, and in panel d, find the T.*
Sometimes people search for information quite effectively, although their attention is divided. How can they do this? One way is through a feature inhibition mechanism (Treisman & Sato, 1990). Here, inhibition or suppression occurs of irrelevant features that might distract an individual from being able to search for a target. There is some neuropsychological support for Treisman’s model. For example, Nobel laureates David Hubel and Torsten Wiesel (1979) have identified specific neural feature detectors. These are cortical neurons that respond differentially to visual stimuli of particular orientations. Examples of such orientations would be vertical, horizontal, or diagonal. More recently, investigators have identified additional cortical processes involved in the various distinct steps of feature integration required for a variety of tasks (Bachevalier & Mishkin, 1986; Mishkin & Appenzeller, 1987; Mishkin, Ungerleider, & Macko, 1983). These tasks include object recognition and visual discrimination. The researchers observed that during visual search, differing neural activity appears to be involved in the relatively low-level identification of features. This is in contrast to the neural activity during relatively high-level featural integration and synthesis. Today we know that processing is more complex than Hubel and Wiesel originally thought. There is parallel processing of color, orientation, motion, depth, and other features (Maunsell, 1995).

**Similarity Theory**

Not everyone agrees with Treisman’s model, however. According to *similarity theory*, Treisman’s data can be reinterpreted. In this view, the data are a result of the fact that as the similarity between target and distracter stimuli increases, so does the difficulty in detecting the target stimuli (Duncan & Humphreys, 1989, 1992). Thus, targets that are highly similar to distracters are hard to detect. Targets that are highly disparate from distracters are easy to detect. For example, try to find the black (filled) circle in Figure 4.4c. The target is highly similar to the distracters (black squares or white circles). It is therefore very difficult to find.

According to this theory, another factor that facilitates the search for target stimuli is similarity (uniformity) among the distracters (Duncan & Humphreys, 1989). Searching for target stimuli against a background of relatively uniform (highly similar) distracters is fairly easy. But searching for target stimuli against a background of highly diverse distracters is quite difficult. Furthermore, the difficulty of search tasks depends on the degree of similarity between the targets and the distracters and on the degree of disparity among the distracters. But it does not depend on the number of features to be integrated. For instance, one reason that it is easier to read long strings of text written in lowercase letters than text written in capital letters is that capital letters tend to be more similar to one another in appearance. Lowercase letters, in contrast, have more distinguishing features. However, as in the initial letter of a sentence or of a word in a title, capital letters are quite distinctive from lowercase letters. You can get an idea of how highly dissimilar distracters impede visual search. Try to find the capital letter R in panels f and g of Figure 4.4d.

In addition, some findings do not fit well with Treisman’s theory. For example, some features (e.g., size and color) may be conjoined easily even without attentional processes. Search for these integrated features appears to occur about as rapidly as does search for some discrete features (He & Nakayama, 1992; Nakayama, 1990). It
**FIGURE 4.4C**

In panel e, find the black circle.

**FIGURE 4.4D**

In panels f and g, find the R.
would be about as easy to search for objects with conjoined features of size and color as it would be to search for objects of a distinctive color alone. For instance, it would be as easy to search for large red circles (target stimuli) versus small red circles, large blue circles, and small blue circles (distracters) as it would be to search for red circles (target stimuli) versus blue circles (distracters). Thus, the difficulty of visual search depends not only on whether discrete features must be integrated. It also depends on which features must be integrated in a given search.

**Guided Search Theory**

In response to these and other findings, investigators have proposed an alternative to Treisman’s model. They call it *guided search* (Cave & Wolfe, 1990). According to these researchers, the guided-search model suggests that all searches, whether feature searches or conjunction searches, involve two consecutive stages. The first is a parallel stage. In it, the individual simultaneously activates a mental representation of all the potential targets. The representation is based on the simultaneous activation of each of the features of the target. In a subsequent serial stage, the individual sequentially evaluates each of the activated elements, according to the degree of activation. He or she then chooses the true targets from the activated elements. According to this model, the activation process of the parallel initial stage helps to guide the evaluation and selection process of the serial second stage of the search.

Let’s see how guided search might work. Try to find the white circles in panel *h* of Figure 4.4 *e*. In this case, the targets are all white circles. The distracters are all black squares. Thus, we have a feature search. So the parallel stage will activate all the circles, but it will activate none of the squares. Therefore, the serial stage quickly will be able to select all the targets. However, look at panel *i* of Figure 4.4 *e*. Try to find the black circle. The distracters include white squares, white circles, and black squares. Hence, the parallel stage will activate a mental map for the target black circle. This is the top-priority activation because of the conjunction of features. For the distracter, it will activate black squares and white circles. During the serial stage, you first will evaluate the black circle, which was highly activated. But then you will evaluate the black squares and the white circles, which were less highly activated. You then will dismiss them as distracters.

Cave and Wolfe’s guided-search model predicts that some conjunction searches are easier than others. In particular, those involving more items with features similar to those of the target are easier than those involving fewer items with features similar to those of the target. These researchers found support for their model by creating computer simulations. They then compared the performance of the simulations with the actual performance of participants carrying out searches. Under most circumstances, the simulations of their model produced results that were very similar to those of the actual participants.

**Final Considerations**

Suppose we know in advance the general area in which to expect a stimulus to be located. We then can find the stimulus much more readily (Posner, Snyder, & Davidson, 1980). For example, consider panel *j* of Figure 4.4 *f*. Once we detect the spatial pattern regarding where to expect the target stimulus, our search becomes easier. Prior
In panel h, find the white (hollow) circles, and in panel i, find the black circle.

In panel j, find the deviant stimulus in each subarray. In panels k and l, find all instances of the letters p and a.
knowledge also influences our ability to use various strategies for conjunctive searches. For example, for most people over age 7 years, it will be relatively easy to find the instances of the letters a and p in panel k of Figure 4.4 f. Similarly, anyone who is experienced at touch-typing can readily find the instances of those letters in panel l of Figure 4.4 f. In both cases, prior knowledge may facilitate visual search.

**Selective and Divided Attention**

**Basic Paradigms for Studying Selective Attention**

Suppose you are at a dinner party. It is just your luck that you are sitting next to a salesman. He sells 110 brands of vacuum cleaners. He describes to you in excruciating detail the relative merits of each brand. As you are listening to this blatherer, who happens to be on your right, you become aware of the conversation of the two diners sitting on your left. Their exchange is much more interesting. It contains juicy information you had not known about one of your acquaintances. You find yourself trying to keep up the semblance of a conversation with the blabbermouth on your right, but you are also tuning in to the dialogue on your left.

The preceding vignette describes a naturalistic experiment in selective attention. It was inspired by the research of Colin Cherry (1953). Cherry referred to this phenomenon as the **cocktail party problem**, the process of tracking one conversation in the face of the distraction of other conversations. He observed that cocktail parties are often settings in which selective attention is salient. The preceding is a good example.

Cherry did not actually hang out at numerous cocktail parties to study conversations. He studied selective attention in a more carefully controlled experimental setting. He devised a task known as shadowing. In shadowing, you listen to two different messages. You are required to repeat back only one of the messages as soon as possible after you hear it. In other words, you are to follow one message (think of a detective “shadowing” a suspect) but ignore the other. For some participants, he used binaural presentation, presenting the same two messages or sometimes just one message to both ears simultaneously. For other participants, he used dichotic presentation, presenting a different message to each ear. (Figure 4.5 illustrates how these listening tasks might be presented.)

Cherry’s participants found it virtually impossible to track only one message during simultaneous binaural presentation of two distinct messages. It is as though in attending to one thing, we divert attention from another (Desimone & Duncan, 1995; Duncan, 1996). His participants much more effectively shadowed distinct messages in dichotic-listening tasks. In such tasks they generally shadowed messages fairly accurately. During dichotic listening, participants also were able to notice physical, sensory changes in the unattended message—for example, when the message was changed to a tone or the voice changed from a male to a female speaker. However, they did not notice semantic changes in the unattended message. They failed to notice even when the unattended message shifted to English or German or was played backward. Conversely, about one third of people, when their name is presented during these situations, will switch their attention to their name. Some researchers have
noted that those who hear their name in the unattended message tend to have limited working-memory capacity. As a result, they are easily distracted (Conway, Cowan, & Bunting, 2001). Infants will also shift their attention to one of two messages if their name is said (Newman, 2005).

Think of being at a cocktail party or in a noisy restaurant. Three factors help you to selectively attend only to the message of the target speaker to whom you wish to listen. The first is distinctive sensory characteristics of the target’s speech. Examples of such characteristics are high versus low pitch, pacing, and rhythmicity. A second is sound intensity (loudness), and a third is location of the sound source (Brungard & Simpson, 2007). Attending to the physical properties of the target speaker’s voice has its advantages. You can avoid being distracted by the semantic content of messages from nontarget speakers in the area. Clearly, the sound intensity of the target also helps. In addition, you probably intuitively can use a strategy for locating sounds. This changes a binaural task into a dichotic one. You turn one ear toward and the other ear away from the target speaker. Note that this method offers no greater total sound intensity. The reason is that with one ear closer to the speaker, the other is farther away. The key advantage is the difference in volume. It allows you to locate the source of the target sound.

**Filter and Bottleneck Theories of Selective Attention**

Models of selective attention can be of several different kinds (Bundesen, 1996, 2000; Logan, 1996). The models differ in two ways. First, do they have a distinct “filter” for incoming information? Second, if they do, where in the processing of information does the filter occur (Pashler, 1998)?
**Broadbent’s Model**

According to one of the earliest theories of attention, we filter information right after it is registered at the sensory level (Broadbent, 1958; Figure 4.6). In Broadbent’s view, multiple channels of sensory input reach an attentional filter. It permits only one channel of sensory information to proceed through the filter to reach the processes of perception. We thereby assign meaning to our sensations. In addition to the target stimuli, stimuli with distinctive sensory characteristics may pass through the attentional system. Examples would be differences in pitch or in loudness. They thereby reach higher levels of processing, such as perception. However, other stimuli will be filtered out at the sensory level. They may never pass through the attentional filter to reach the level of perception. Broadbent’s theory was supported by Colin Cherry’s findings that sensory information may be noticed by an unattended ear. Examples of such material would be male versus female voices or tones versus words. But information requiring higher perceptual processes is not noticed in an unattended ear. Examples would be German versus English words or even words played backward instead of forward.

**FIGURE 4.6**

Various mechanisms have been proposed suggesting a means by which incoming sensory information passes through the attentional system to reach high-level perceptual processes.
Moray’s Selective Filter Model
Not long after Broadbent’s theory, evidence began to suggest that Broadbent’s model must be wrong (e.g., Gray & Wedderburn, 1960). First, an investigator found that even when participants ignore most other high-level (e.g., semantic) aspects of an unattended message, they frequently still recognize their names in an unattended ear (Moray, 1959). He suggested that the reason for this effect is that powerful, highly salient messages may break through the filter of selective attention. But other messages may not. To modify Broadbent’s metaphor, one could say that, according to Moray, the selective filter blocks out most information at the sensory level. But some highly salient, or personally important, messages are so powerful that they burst through the filtering mechanism.

Treisman’s Attenuation Model
While a participant is shadowing a coherent message in one ear and ignoring a message in the other ear, something interesting occurs. If the message in the attended ear suddenly is switched to the unattended ear, participants will pick up the first few words of the old message in the new ear (Treisman, 1960). This finding suggests that context briefly will lead the participants to shadow a message that should be ignored.

Moreover, if the unattended message was identical to the attended one, all participants noticed it. They noticed even if one of the messages was slightly out of temporal synchronization with the other (Treisman, 1964a, 1964b). Participants typically recognized the two messages to be the same when the shadowed message was as much as 4.5 seconds ahead of the unattended one. They also recognized it if it was as far as 1.5 seconds behind the unattended one. Treisman also observed fluently bilingual participants. Some of them noticed the identity of messages if the unattended message was a translated version of the attended one.

Moray’s modification of Broadbent’s filtering mechanism was clearly not sufficient to explain Treisman’s (1960, 1964a, 1964b) findings. Her findings suggested to Treisman that at least some information about unattended signals is being analyzed. Treisman also interpreted Moray’s findings as indicating that some higher-level processing of the information reaching the supposedly unattended ear must be taking place. Otherwise, participants would not recognize the familiar sounds to realize that they were salient. That is, the incoming information cannot be filtered out at the level of sensation. If it were, we would never perceive the message to recognize its salience.

Based on these findings, Treisman proposed a theory of selective attention. It involves a different kind of filtering mechanism. Recall that in Broadbent’s theory the filter acts to block stimuli other than the target stimulus. In Treisman’s theory, however, the mechanism merely attenuates (weakens the strength of) stimuli other than the target stimulus. For particularly potent stimuli, the effects of the attenuation are not great enough to prevent the stimuli from penetrating the signal-weakening mechanism. Figure 4.6 illustrates Treisman’s signal-attenuating mechanism.

According to Treisman, selective attention involves three stages. In the first stage, we preattentively analyze the physical properties of a stimulus. Examples would be loudness (sound intensity) and pitch (related to the “frequency” of the sound waves. This preattentive process is conducted in parallel (simultaneously) for all incoming sensory stimuli. For stimuli that show the target properties, we pass the signal on to the next stage. For stimuli that do not show these properties, we pass on only a weakened version...
of the stimulus. In the second stage, we analyze whether a given stimulus has a pattern, such as speech or music. For stimuli that show the target pattern, we pass the signal on to the next stage. For stimuli that do not show the target pattern, we pass on only a weakened version of the stimulus. In the third stage we focus attention on the stimuli that make it to this stage. We sequentially evaluate the incoming messages. We assign appropriate meanings to the selected stimulus messages.

**Deutsch and Deutsch’s Late Filter Model**

Consider an alternative to Treisman’s attenuation theory. It simply moves the location of the signal-blocking filter to follow, rather than precede, at least some of the perceptual processing needed for recognition of meaning in the stimuli. In this view, the signal-blocking filter occurs later in the process. It has its effects after sensory analysis. Thus, it occurs after some perceptual and conceptual analysis has occurred (Deutsch & Deutsch, 1963; Norman, 1968; Figure 4.7). This later filtering would allow people to recognize information entering the unattended ear. For example, they might recognize the sound of their own names or a translation of attended input (for bilinguals). If the information does not perceptually strike some sort of chord, people will throw it out at the filtering mechanism shown in Figure 4.7. If it does, however, as with the sound of an important name, people will pay attention to it. Note that proponents of both the early and the late filtering mechanisms propose that there is an attentional bottleneck through which only a single source of information can pass. The two models differ only in terms of where they hypothesize the bottleneck to be positioned.

**The Multimode Theory**

Multimode theory (Johnston & Heinz, 1978) proposes that attention is flexible. Selection of one message over another message can be made at any of various different points in the course of information processing. According to this theory, processing

---

**FIGURE 4.7**

According to some cognitive psychologists, the attentional filtering mechanisms follow, rather than precede, preliminary perceptual processes.
occurs in three stages. In Stage 1, the individual constructs sensory representations of stimuli. In Stage 2, the individual constructs semantic representations. Neither of these stages is fully conscious. In Stage 3, the representations of Stages 1 and 2 become conscious. Early selection (Broadbent) would be associated with Stage 1, whereas late selection would be associated with Stage 3. The difficulty of a task requiring selection depends, in part, upon when selection takes place. More effort is required in later than in earlier stages.

**Neisser's Synthesis**

In 1967, Ulric Neisser synthesized the early-filter and the late-filter models in a way different from Johnston and Heinz (1978). He proposed that there are two processes governing attention: preattentive and attentive processes. Preattentive, automatic processes are rapid and occur in parallel. They can be used to notice only physical sensory characteristics of the unattended message. But they do not discern meaning or relationships. Attentive, controlled processes occur later. They are executed serially and consume time and attentional resources, such as working memory. They also can be used to observe relationships among features. They serve to synthesize fragments into a mental representation of an object. More recent work in attention builds on Neisser’s distinction between preattentive and attentive processes. It focuses only on the consciously controlled aspects of attention (Cowan, 1995).

Consider a different view of the two processes (McCann & Johnston, 1992). According to these researchers, physical analysis of sensory data occurs continually, but semantic analysis of stimuli occurs only when cognitive capacity (in the form of working memory) is not already overtaxed; the capacity also must be sufficient to permit such analysis. Supportive evidence is that people show much faster reaction times when responding to physically discriminable stimuli than to semantically discriminable stimuli.

A two-step model of some sort could account for Cherry’s, Moray’s, and Treisman’s data. Evidence of fully automatic versus fully controlled processes also seems to support this model. Automatic processes may be governed only by the first step of attentional processing. Controlled processes additionally may be governed by the second of the two steps. The model also nicely incorporates aspects of Treisman’s signal-attenuation theory and of her subsequent feature-integration theory. According to this latter theory, discrete processes for feature detection and for feature integration occur during searches. Again, Treisman’s feature-detection process may be linked to the former of the two processes (i.e., speedy, automatic processing). Her feature-integration process may be linked to the latter of the two processes (i.e., slower, controlled processing). Unfortunately, however, the two-step model does not do a good job of explaining the continuum of processes from fully automatic ones to fully controlled ones. Recall, for example, that fully controlled processes appear to be at least partially automatized (Spelke, Hirst, & Neisser, 1976). How does the two-process model explain the automatization of processes in divided-attention phenomena? For example, how can one read for comprehension while writing dictated, categorized words?

**Attentional-Resource Theories of Selective Attention**

More recent theories have moved away from the notion of signal-blocking or signal-attenuating filters. They have instead moved toward the notion of apportionment of limited attentional resources. Attentional-resource theories help to explain how we
can perform more than one attention-demanding task at a time. They posit that people have a fixed amount of attention that they can choose to allocate according to what the task requires. Figure 4.8 shows two examples of such a theory. In panel a, the system has a single pool of resources that can be divided up, say, among multiple tasks (Kahneman, 1973).

However, it now appears that such a model represents an oversimplification. People are much better at dividing their attention when competing tasks are in different modalities. At least some attentional resources may be specific to the modality in which a task is presented. For example, most people easily can simultaneously listen to music and concentrate on writing. But it is harder to listen to the news station and concentrate on writing at the same time. The reason is that both are verbal tasks. The words from the news interfere with the words you are thinking about. Similarly, two visual tasks are more likely to interfere with each other than are a visual task coupled with an auditory one. Panel b of Figure 4.8 shows a model that allows for attentional resources to be specific to a given modality (Navon & Gopher, 1979). For someone trying to write while listening to music, the use of two distinctive modality-specific attentional resources probably would not pose serious attentional difficulties. An example would be auditory for music, writing for visual.

Attentional-resources theory has been criticized severely as overly broad and vague (e.g., S. Yantis, personal communication, December 1994). Indeed, it may not stand alone in explaining all aspects of attention, but it complements filter theories quite well. Filter and bottleneck theories of attention seem to be more suitable metaphors for competing tasks that appear to be attentionally incompatible. Examples would be selective-attention tasks or simple divided-attention tasks involving the
psychological refractory period (PRP) effect (Pashler, 1994). For these kinds of tasks, it appears that some preattentive processes may occur simultaneously, but processes requiring attention must be handled sequentially, as if passing one-by-one through an attentional bottleneck.

Resource theory seems to be a better metaphor for explaining phenomena of divided attention on complex tasks. In these tasks, practice effects may be observed. According to this metaphor, as each of the complex tasks becomes increasingly automated, performance of each task makes fewer demands on the limited-capacity attentional resources. Additionally, for explaining search-related phenomena, theories specific to visual search (e.g., models proposing guided search [Cave & Wolfe, 1990] or similarity [Duncan & Humphreys, 1989]) seem to have stronger explanatory power than do filter or resource theories. However, these two kinds of theories are not altogether incompatible. Although the findings from research on visual search do not conflict with filter or resource theories, the task-specific theories more specifically describe the processes at work during visual search.

**Additional Considerations in Selective Attention**

**The Role of Task, Situation, and Person Variables**
The existing theoretical models of attention may be too simplistic and mechanistic to explain the complexities of attention. For example, both trait-based anxiety (a personality characteristic) and situation-related anxiety have been found to affect attention (Eysenck & Byrne, 1992; Eysenck & Calvo, 1992; Eysenck & Graydon, 1989). Both types of anxiety tend to place constraints on attention. Other considerations enter in as well. The first is overall arousal. One may be tired, drowsy, or drugged, which may limit attention. Being excited sometimes enhances it. A second consideration is specific interest in a target task and stimuli, compared with interest in distracters. A third is the nature of the task. For example, it may be highly difficult, complex, or novel. Such tasks require more attentional resources than do easy, simple, or highly familiar tasks. Task difficulty particularly influences performance during divided attention. A fourth consideration is amount of practice in performing a given task or set of tasks. Related to this is the skill of utilizing attentional resources for a task or tasks. Increased practice and skill enhance attention (Spelke, Hirst, & Neisser, 1976). A fifth consideration is the stage of processing at which attentional demands are needed. This stage may be before, during, or after some degree of perceptual processing.

In sum, certain attentional processes occur outside our conscious awareness. Others are subject to conscious control. The psychological study of attention has included diverse phenomena, such as vigilance, search, selective attention, and divided attention during the simultaneous performance of multiple tasks. To explain this diversity of attentional phenomena, current theories emphasize that a filtering mechanism appears to govern some aspects of attention. Limited modality-specific attentional resources appear to influence other aspects of attention. Clearly, findings from cognitive research have yielded many insights into attention, but additional understanding also has been gained through the study of attentional processes in the brain.
**The Stroop Effect**

Much of the research on selective attention has focused on auditory processing, but selective attention also can be studied through visual processing. One of the tasks most frequently used for this purpose was first formulated by John Ridley Stroop (1935). The Stroop effect is named after him. The task works as follows:

Quickly read aloud the following words: brown, blue, green, red, purple. Easy, isn’t it? Now quickly name aloud the colors shown in part a of the top figure on the back endpaper of this book. In this figure, the colored ink matches the name of the color word. This task, too, is easy. Now, look at part c of the same figure. Here, the colors of the inks differ from the color names that are printed with them. Again, name the ink colors you see, out loud, as quickly as possible.

You probably will find the task very difficult: Each of the written words interferes with your naming the color of the ink. The *Stroop effect* demonstrates the psychological difficulty in selectively attending to the color of the ink and trying to ignore the word that is printed with the ink of that color. One explanation of why the Stroop test may be particularly difficult is that, for you and most other adults, reading is now an automatic process. It is not readily subject to your conscious control (MacLeod, 1991, 1996). For that reason, you find it difficult intentionally to refrain from reading and instead to concentrate on identifying the color of the ink, disregarding the word printed in that ink color. An alternative explanation is that the output of a response occurs when the mental pathways for producing the response are activated sufficiently (MacLeod, 1991). In the Stroop test, the color word activates a cortical pathway for saying the word. In contrast, the ink-color name activates a pathway for naming the color. But the former pathway interferes with the latter. In this situation, it takes longer to gather sufficient strength of activation to produce the color-naming response and not the word-reading response.

A number of variations of the Stroop effect exist, including the number Stroop, the directional Stroop, the animal Stroop, and the emotional Stroop. These tasks are very similar to the standard Stroop. For example, in the number Stroop, number words are used. Thus, the word *two* might be written three times, *two two two*, and the participant be asked to count the number of words. As with the standard Stroop task, reading sometimes interferes with the counting task (Girelli & associates, 2001; Kaufmann & Nuerk, 2006). One of the most extensively used Stroop variations is the emotional Stroop. In this task, the standard task is modified so that the color words are replaced with either emotional or neutral words. Participants are asked to name the colors of the words. Researchers find that there is a longer delay in color naming for emotional words as compared with neutral words. These findings suggest that the automatic reading of emotional words causes more interference than reading of neutral words (Borkenau & Mauer, 2006; Larsen, Mercer, & Balota, 2006; Phaf & Kan, 2007; Thomas, Johnstone, & Gonsalvez, 2007).

**Divided Attention**

In signal detection and selective attention, the attentional system must coordinate a search for the simultaneous presence of many features. This is a relatively simple, if not easy, task. At times, however, the attentional system must perform two or more discrete tasks at the same time. Early work in this area was done by Ulric Neisser and
Robert Becklen (1975). They had participants view a videotape in which the display of one activity was superimposed on the display of another activity. The first activity was a three-person basketball game; the second, two people playing a hand-slapping game. Initially, the task was simply to watch one activity and ignore the other. The participant pressed a button whenever key events occurred in the attended activity. Essentially, this first task required only selective attention.

However, the two researchers then asked participants to attend to both activities simultaneously. They were to signal key events in each of the two activities. Even when the researchers presented the two activities dichoptically (i.e., not in a single visual field, but rather with one activity observed by one eye and the other activity observed by the other eye), participants had great difficulty performing both tasks simultaneously. Neisser and Becklen hypothesized that improvements in performance would have occurred eventually as a result of practice. They also hypothesized that the performance of multiple tasks was based on skill resulting from practice. They believed it not to be based on special cognitive mechanisms.

The following year, investigators used a dual-task paradigm to study divided attention during the simultaneous performance of two activities (Spelke, Hirst, & Neisser, 1976). The dual-task paradigm involves two tasks (Task A and Task B) and three conditions (Task A only, Task B only, and both Tasks A and B). The idea was that the researchers would compare and contrast the latency (response time) and accuracy of performance in each of the three conditions. Of course, higher latencies mean slower responses. Previous research had shown that the speed and accuracy of simultaneous performance of two controlled processes was quite poor for the simultaneous performance of two controlled processes. There are rare instances in which people demonstrate high levels of speed and accuracy for the simultaneous performance of two tasks. In those instances, at least one of the tasks generally involves automatic processing, and usually both tasks involve such processing.

As expected, initial performance was indeed quite poor for the two controlled tasks they chose. These two tasks were reading for detailed comprehension and writing down dictated words. However, Spelke and her colleagues continued to have the two participants in their study perform these two tasks 5 days a week for many weeks (85 sessions in all). To the surprise of many, given enough practice, the participants’ performance improved on both tasks. They showed improvements in their speed of reading and accuracy of reading comprehension, as measured by comprehension tests. They also showed increases in their recognition memory for words they had written during dictation. Eventually, participants’ performance on both tasks reached the same levels that the participants previously had shown for each task alone.

The authors then introduced sublists of related words within the full word-dictation lists. Examples would be sublists of words that formed a sentence or rhymed. They asked the participants to report any of the words that had been dictated, or any general properties of the particular list that they remembered. The participants initially recalled very few words and no relationships among any of the words. After repeated practice, however, they noticed words related in various ways. One was by superordinate categories. A second was by rhyming sounds. A third was by strings of words that formed sentences. And a fourth was by parts of speech. They included grammatical classes, such as verbs and plural nouns. Furthermore, simultaneous performance of the more complex dictation task initially led to a dip in performance on
the reading-comprehension task. With continued practice, performance on that task soon returned to previous high levels.

Next, the authors modified the word-dictation task. Now, the participants sometimes wrote the dictated words and sometimes wrote the correct one of two categories (e.g., animals versus furniture) to which the dictated words belonged. At the same time, they still engaged in the reading-comprehension task. As with previous modifications, initial performance on the two tasks dropped. But performance returned to high levels after practice. Spelke and her colleagues suggested that these findings showed that controlled tasks can be automatized so that they consume fewer attentional resources. Further, two discrete controlled tasks may be automatized to function together as a unit. These authors were quick to point out that the tasks do not, however, become fully automatic. For one thing, they continue to be intentional and conscious. For another, they involve relatively high levels of cognitive processing.

An entirely different approach to studying divided attention has focused on extremely simple tasks that require speedy responses. When people try to perform two overlapping speeded tasks, the responses for one or both tasks are almost always slower (Pashler, 1994). When a second task begins soon after the first task has started, speed of performance usually suffers. The slowing resulting from simultaneous engagement in speeded tasks, as mentioned earlier in the chapter, is the PRP effect. Findings from PRP studies indicate that people can accommodate fairly easily perceptual processing of the physical properties of sensory stimuli while engaged in a second speeded task (Pashler, 1994). However, they cannot readily accommodate more than one cognitive task requiring them to choose a response, retrieve information from memory, or engage in various other cognitive operations. When both tasks require performance of any of these cognitive operations, one or both tasks will show the PRP effect.

Consider driving a car, for example. You need constantly to be aware of threats to your safety. Suppose you fail to select one such threat, such as a car that runs a red light and is headed directly at you as you enter an intersection. The result is that you may become an innocent victim of a horrible car accident. Moreover, if you are unsuccessful in dividing your attention, you may cause an accident. Most automobile accidents are caused by failures in divided attention. A study of 2700 crashes in the state of Virginia between June and November of 2002 investigated causes of accidents (Warner, 2004). According to the study, rubbernecking (viewing accidents that have already occurred) was the cause of 16% of accidents, followed by driver fatigue (12%); looking at scenery or landmarks (10%); distractions caused by passengers or children (9%); adjusting a radio, tape, or CD player (7%); and cell phone use (5%). On average, distractions occurring inside the vehicle accounted for 62% of the distractions reported. Distractions outside the vehicle accounted for 35%. The other 3% were of undetermined cause. The causes of accidents differed somewhat for rural versus urban areas. Accidents in rural areas were more likely to be due to driver fatigue, insects entering or striking the vehicle, or pet distractions. In urban areas, crashes were more likely to result from rubbernecking, traffic, or cell-phone use. Overall, this study and others suggested that cell phones are somewhat less responsible for accidents than some people had expected (Cohen & Graham, 2003; Figure 4.9).

As many as 21% of accidents and near-accidents involve at least one driver talking on a cell phone, although the conversation may or may not have been the cause of the accident (Seo & Torabi, 2004). Other research has indicated that, when time...
on task and driving conditions are controlled for, the effects of talking on a cell phone can be as detrimental to driving as intoxication (Strayer, Drews, & Crouch, 2006). Still other research has found that, compared with people not on a cell phone, people talking on a cell phone exhibit more anger, through honking and facial expressions, when presented with a frustrating situation (McGarva, Ramsey, & Shear, 2006). Increased aggression has been linked with increased accidents (Deffenbacher & associates, 2003). Therefore, it is likely that people who talk on the phone while driving are more prone to anger and, as a result, more accidents. These findings, combined with those on the effects of divided attention, help to explain why an increase in accidents is seen when cell phones are involved.

There are many ways to study divided attention (Egeth, 2000; Luck & associates, 1996; Moore & Egeth, 1997; Pashler, 1998; Pashler & Johnston, 1998; Van der Heijden, 1992). One of the simplest starts with our own set of everyday experiences. One widely used paradigm makes use of a simulation of the driving situation (Strayer & Johnston, 2001). Researchers had participants perform a tracking task. The participants had control of a joystick, which moved a cursor on a computer screen. The participants needed to keep the cursor in position on a moving target. At various times, the target would flash either green or red. If the color was green, the participants were to ignore the signal. If the color was red, however, the participants were to push a simulated brake. The simulated brake was a button on the joystick.

In one condition, participants did the task singly—that is, by itself. In another condition, participants were involved in a second task. This procedure created a dual-
task situation. The participants either listened to a radio broadcast while doing the task or talked on a cell phone to an experimental confederate. Participants talked roughly half the time and also listened roughly half the time. Two different topics were used to ensure that the results were not due to the topic of conversation. The results of the study are shown in Figure 4.10.

As shown in Figure 4.10, the probability of a miss in the face of the red signal increased substantially in the cell-phone dual-task condition relative to the single-
task condition. Reaction times were also substantially slower in this condition than in the single-task condition. In contrast, there was no significant difference between probabilities of a miss in the single-task and radio dual-task condition, nor was there a significant difference in reaction time in this condition. Thus, use of cell phones appears to be substantially more risky than listening to the radio while driving.

**Consciousness of Complex Mental Processes**

No serious investigator of cognition believes that people have conscious access to very simple mental processes. For example, none of us has a good idea of the means by which we recognize whether a printed letter such as A is an uppercase or lowercase one. But now consider more complex processing. How conscious are we of our complex mental processes? Cognitive psychologists have differing views on how this question is best answered.

One view (Ericsson & Simon, 1984) is that people have quite good access to their complex mental processes. Simon and his colleagues, for example, have used protocol analysis in analyzing people’s solving of problems, such as chess problems and so-called cryptarithmetric problems, in which one has to figure out what numbers substitute for letters in a mathematical computation problem. These investigations have suggested to Simon and his colleagues that people have quite good conscious access to their complex information processes.

A second view is that people’s access to their complex mental processes is not very good (e.g., Nisbett & Wilson, 1977). In this view, people may think they know how they solve complex problems, but their thoughts are frequently erroneous. According to Nisbett and Wilson, we typically are conscious of the products of our thinking, but only vaguely conscious, if at all, of the processes of thinking. For example, suppose you decide to buy one model of bicycle over another. You certainly will know the product of the decision—which model you bought. But you may have only a vague idea of how you arrived at that decision. Indeed, according to this view, you may believe you know why you made the decision, but that belief is likely to be flawed. Advertisers depend on this second view. They try to manipulate your thoughts and feelings toward a product so that, whatever your conscious thoughts may be, your unconscious ones will lead you to buy their product over that of a competitor.

The essence of the second view is that people’s conscious access to their thought processes, and even their control over their thought processes, is quite minimal (Wegner, 2002; Wilson, 2002). Consider the problem of getting over someone who has terminated an intimate relationship with you. One technique that is sometimes used to get over someone is thought suppression. As soon as you think of the person, you try to put the individual out of your mind. There is one problem with this technique, but it is a major one: It often does not work. Indeed, the more you try not to think about the person, the more you may end up thinking about him or her and having trouble getting the person off your mind. Research has actually shown that trying not to think about something usually does not work (Wegner, 1997a, 1997b). Ironically, the more you try not to think about someone or something, the more “obsessed” you may become with the person or object.
Change Blindness

Adaptive behavior requires us to be attentive to changes in our environment because changes cue us to both opportunities and dangers. Evolutionarily, the ability to spot predators suddenly appearing in the visual field would have been a great advantage for the survival of organisms and, ultimately, their genes. It thus may be surprising to discover that people can show remarkable levels of change blindness, the inability to detect changes in objects or scenes that are being viewed (O’Regan, 2003; Simons, 2000).

In one study, a stranger asks a bystander for directions. As the interaction proceeds, two workers carrying a wooden door walk between the stranger and the bystander. When the workers have passed by, the original stranger has been replaced by a different stranger (one of the workers). The interaction then continues as before. How likely do you think it is that the bystander would notice that the person to whom he or she is talking is no longer the same person? Oddly enough, only about half of the bystanders notice that a switch has been made. Many do not even notice the change when they are explicitly told that the person to whom they are talking is not the one with whom they originally were conversing (Simons & Levin, 1997, 1998).

In another paradigm, participants see pairs of pictures, separated by brief intervals. Changes are made in the pictures in the interval. For the most part, people have difficulty recognizing the changes. They are more likely to recognize them when they are important to the scene than when they are unimportant. Even when told explicitly to look for changes, people have trouble finding them (Levin & Simons, 1997; Rensink, O’Regan, & Clark, 1997; Shore & Klein, 2000; Simons, 2000; Simons & Ambinder, 2005).

There do seem to be cultural differences in the areas that we observe changes. In American participants, central items are recognized more readily than peripheral changes. However, in East Asian participants, changes in peripheral information are more promptly identified compared with central changes (Masuda & Nisbett, 2006). The right parietal cortex plays a significant role in change blindness. Electrical stimulation to this area increases the time it takes to identify a change in a scene (Beck & associates, 2006).

Change blindness is not limited to visual information. The inability to detect a change can be observed in auditory and tactile stimuli (Gallace & associates, 2006; Vitevitch, 2003). However, as in visual stimuli, a brief delay must be present between the original and changed stimuli.

These results suggest that people are much less astute in recognizing changes in their environments than we might expect. Even fairly blatant changes, such as the identity of a person to whom we speak, may pass us by. When we admire Sherlock Holmes for his astuteness, we probably give him too little credit. In the fictional detective stories in which he plays a role, he notices extremely unobvious things. Often we tend not to notice even things that are obvious.

Attention Deficit Hyperactivity Disorder

Most of us take for granted our ability to pay attention and to divide our attention in adaptive ways. But not everyone can do so. People with attention deficit hyperactivity disorder (ADHD) have difficulties in focusing their attention in ways that
enable them to adapt in optimal ways to their environment (Attention deficit hyperactivity disorder, 2004, upon which this section is largely based; see also Swanson & associates, 2003). This condition typically first displays itself during the preschool or early school years. It is estimated that 3% to 5% of children have the disorder, meaning that in the United States roughly 2 million children exhibit symptoms. Some studies have suggested that the rate of ADHD is much higher, affecting up to 12% of children worldwide (Biederman & Faraone, 2005). The disorder does not typically end in adulthood, although it may vary in its severity, becoming either more or less severe.

The condition was first described by Dr. Heinrich Hoffman in 1845. Today, it has been widely investigated. No one knows for sure the cause of ADHD. It may be a partially heritable condition. There is some evidence of a link to maternal smoking and drinking of alcohol during pregnancy (Hausknecht & associates, 2005; Rodriguez & Bohlin, 2005). Lead exposure on the part of the child may also be associated with ADHD. Brain injury is another possible cause, as are food additives—in particular, sugar and certain dyes (Cruz & Bahna, 2006). There are noted differences in the frontal-subcortical cerebellar catecholaminergic circuits and in dopamine regulation in people with ADHD (Biederman & Faraone, 2005).

There is some evidence that the incidence of ADHD has increased in recent years. During the period from 2000 to 2005, the prevalence of medicinal treatment increased by more than 11% each year (Castle & associates, 2007). The reasons for this increase are not clear. Various hypotheses have been put forward, including increased watching of fast-paced television shows, use of fast-paced video games, additives in foods, and increases in unknown toxins in the environment.

The three primary characteristics of ADHD are inattention, hyperactivity (i.e., levels of activity that exceed what is normally shown by children of a given age), and impulsiveness. There are three main types. One is predominantly hyperactive-impulsive. The second is predominantly inattentive. The third combines inattentiveness with hyperactivity and impulsiveness. I describe the inattentive type here because it is most relevant to the topic of this chapter.

Children with the inattentive type of ADHD show several distinctive symptoms. First, they are easily distracted by irrelevant sights and sounds. Second, they often fail to pay attention to details. Third, they are susceptible to making careless mistakes in their work. Fourth, they often fail to read instructions completely or carefully. Fifth, they are susceptible to forgetting or losing things they need for tasks, such as pencils or books. Finally, they tend to jump from one incompleted task to another.

ADHD is most often treated with a combination of psychotherapy and drugs. Some of the drugs currently used to treat ADHD are Ritalin (methylphenidate), Metadate (methylphenidate), and Strattera (atomoxetine). This last drug differs from other drugs used to treat ADHD in that it is not a stimulant. Rather, it affects the neurotransmitter norepinephrine. The stimulants, in contrast, affect the neurotransmitter dopamine. Interestingly, in children, the rate of boys who are given medication for treatment of ADHD is more than double that of girls. However, in adults, the use of ADHD medication is approximately equal for both sexes (Castle & associates, 2007). A number of studies have noted that, although medication is a useful tool in the treatment of ADHD, it is best used in combination with behavioral interventions (Corcoran & Dattalo, 2006; Rostain & Tamsay, 2006).
Cognitive Neuroscientific Approaches to Attention and Consciousness

The neuroscience of attention has an ever-growing body of literature. Consider an attempt to synthesize diverse studies investigating attentional processes in the brain (Posner, 1992; Posner & Dehaene, 1994; Posner & Raichle, 1994). Is attention a function of the entire brain, or is it a function of discrete attention-governing modules in the brain? According to Posner, the attentional system in the brain “is neither a property of a single brain area nor of the entire brain” (Posner & Dehaene, 1994, p. 75).

Posner and Rothbart (2007) completed a review of neuroimaging studies in the area of attention. What at first seemed like an unclear pattern of activation can be effectively organized into areas associated with the three subfunctions of attention. The researchers define these functions as alerting, orienting, and executive attention. The researchers organized the findings to describe each of these functions in terms of the brain areas involved, the neurotransmitters that modulate the changes, and the results of dysfunction within this system. The following section is closely based on the comprehensive review by Posner and Rothbart (2007).

Alerting is defined as being prepared to attend to some incoming event. Alerting also includes the process of getting to this state of preparedness. The brain areas involved in alerting are the superior parietal, temporal parietal junction, frontal eye field, and superior colliculus. The neurotransmitter that modulates alerting is acetylcholine. Dysfunction of the alerting system is related to attentional changes as we age and to ADHD.

The second function of attention is orienting. Orienting is defined as the selection of stimuli to attend to. The brain areas involved in the orienting function are the locus coeruleus, right frontal, and parietal cortex. The modulating neurotransmitter for orienting is norepinephrine. Dysfunction within this system is related to autism.

The final function defined within attention is executive attention. Executive attention includes processes for monitoring and resolving conflicts that arise among internal processes. These processes include thoughts, feelings, and responses. The brain areas involved in this final and highest order of attentional process are anterior cingulated, lateral ventral, prefrontal, and basal ganglia. The neurotransmitter most involved in the executive attention process is dopamine. Dysfunction within this system is associated with Alzheimer’s disease, borderline personality disorder, and schizophrenia.

Spatial Neglect

Spatial neglect or just neglect is an attentional dysfunction in which participants ignore the half of their visual field that is contralateral, on the opposite side, to the hemisphere of the brain that has a lesion. It is due mainly to unilateral lesions in the parietal lobes. Research reveals that the problem may be a result of the interac-
tion of systems that mutually inhibit one another. When only one of the pair involved in the system is damaged, as is the case with neglect patients, patients become locked in to one side of the visual field. The reason is that the inhibition normally provided by the other half of the system is no longer working. Spatial neglect has been examined by a number of experimenters (Luaute & associates, 2006; Schindler & associates, 2006).

One way to test for neglect is to give patients who are suspected of suffering from neglect a sheet of paper with a number of horizontal lines. Patients are then asked to bisect the lines precisely in the middle of each. Patients with lesions in the right hemisphere tend to bisect the lines to the right of the midline. Patients with lesions in the left hemisphere tend to bisect the lines to the left of the midline. The reason is that the former group of patients does not see all of the lines to the left, whereas the latter group does not see all of the lines to the right. Sometimes patients miss the lines altogether (patients who neglect the entire visual field).

**Attentional Systems**

Posner (1995) has identified an anterior (frontward) attention system (attentional network) within the frontal lobe and a posterior (toward the rear) attention system within the parietal lobe. The anterior attention system becomes increasingly activated during tasks requiring awareness. An example would be tasks in which participants must attend to the meanings of words. This system also is involved in “attention for action.” Here, the participant is planning or selecting an action from among alternative courses of action. In contrast, the posterior attention system involves the parietal lobe of the cortex, a portion of the thalamus, and some areas of the midbrain related to eye movements. This system becomes highly activated during tasks involving visuospatial attention. In these tasks, the participant must disengage and shift attention (e.g., visual search or vigilance tasks) (Posner & Raichle, 1994). Attention also involves neural activity in the relevant visual, auditory, motor, and association areas of the cortex involved in particular visual, auditory, motor, or higher order tasks (Posner & associates, 1988). The anterior and posterior attention systems appear to enhance attention across various tasks. This suggests that they may be involved in regulating the activation of relevant cortical areas for specific tasks (Posner & Dehaene, 1994).

Another question has arisen regarding the activity of the attentional system. This activity occurs as a result of enhanced activation of attended items, inhibition or suppressed activation of unattended items, or both processes. Apparently, it depends on the particular task and on the area of the brain under investigation (Posner & Dehaene, 1994). The task at hand is to determine which processes occur in which areas of the brain during the performance of which tasks. For mapping the areas of the brain involved in various tasks, cognitive neuropsychologists often use positron emission tomography (PET). This technique maps regional cerebral blood flow (see Chapter 2 for a more in-depth discussion of this technique). In one such PET study (Corbetta & associates, 1993), researchers found increased activation in areas responsible for each of the distinct attributes of various search tasks. These include features such as motion, color, and shape and selected versus divided attentional conditions.
Using Event-Related Potentials to Measure Attention

An alternative way of studying attention in the brain is to focus on studying event-related potentials (ERPs; see Chapter 2). They indicate minute changes in electrical activity in response to various stimuli. Both the PET and ERP techniques offer information on the geography (localization) of cerebral activity and on the chronology of cerebral events. However, the PET technique provides higher resolution for spatial localization of cerebral function. The ERP provides much more sensitive indications of the chronology of responses (within milliseconds; Näätänen, 1988a, 1988b, 1990, 1992). Thus, through ERP studies, even extremely brief responses to stimuli may be noticed.

The ERP’s sensitivity to very brief responses has allowed Näätänen and his colleagues (e.g., Cowan & associates, 1993; Näätänen, 1988a, 1988b; Paavilainen & associates, 1993) to examine the specific conditions in which target versus distracter stimuli do or do not prompt attentional responses. For example, Näätänen has found that at least some response to infrequent, deviant auditory stimuli (e.g., peculiar changes in pitch) seems to be automatic. It occurs even when the participant is focusing attention on a primary task and is not consciously aware of the deviant stimuli. These automatic, preconscious responses to deviant stimuli occur whether the stimuli are targets or distracters. The responses occur whether the deviants are widely different from the standard stimuli or are only slightly different from the standard stimuli (Cowan & associates, 1993; Paavilainen & associates, 1993). There is no performance decrement in the controlled task as a result of the automatic response to deviant stimuli (Näätänen, 1990). So it seems that some automatic superficial analysis and selection of stimuli may occur without taxing attentional resources.

Many of the foregoing studies have involved normal participants. But cognitive neuropsychologists also have learned a great deal about attentional processes in the brain by studying people who do not show normal attentional processes, such as people who show specific attentional deficits and who are found to have either lesions or inadequate blood flow in key areas of the brain. Overall attention deficits have been linked to lesions in the frontal lobe and in the basal ganglia (Lou, Henriksen, & Bruhn, 1984); visual attentional deficits have been linked to the posterior parietal cortex and the thalamus, as well as to areas of the midbrain related to eye movements (Posner & Petersen, 1990; Posner & associates, 1988). Work with split-brain patients (e.g., Ladavas & associates, 1994; Luck & associates, 1989) also has led to some interesting findings regarding attention and brain function, such as the observation that the right hemisphere seems to be dominant for maintaining alertness and that the attentional systems involved in visual search seem to be distinct from other aspects of visual attention. Using the variety of methods described here enables researchers to study attention in a way that any one method would not permit (Stuss & associates, 1995).

Another neuroimaging technique that has been used to examine attention is functional magnetic resonance imaging (fMRI; see Chapter 2 for more information). As with other methods, both patient and nonpatient populations have been examined through these methods (Madden & associates, 2007; Weaver & Stevens, 2007).
A Psychopharmacological Approach

Another approach to understanding attentional processes is psychopharmacological research, which evaluates changes in attention and consciousness associated with various chemicals (e.g., neurotransmitters such as acetylcholine or GABA [see Chapter 2], hormones, and even central nervous system stimulants [“uppers”] or depressants [“downers”]; Wolkowitz, Tinklenberg, & Weingartner, 1985). In addition, researchers study physiological aspects of attentional processes at a global level of analysis. For example, overall arousal can be observed through such responses as pupillary dilation, changes in the autonomic (self-regulating) nervous system (see Chapter 2), and distinctive EEG patterns. An area that has long been recognized as crucial to overall arousal is the reticular activating system (RAS; see Chapter 2). Changes in the RAS and in specific measures of arousal have been linked to habituation and dishabituation, as well as to the orienting reflex, in which an individual reflexively responds to sudden changes by reorienting the position of the body toward the source of the sudden change (e.g., sudden noise or a flash of light).

Consider one psychologist’s view of how consciousness and perception interact. Anthony Marcel (1983a) has proposed a model for describing how sensations and cognitive processes that occur outside our conscious awareness may influence our conscious perceptions and cognitions. According to Marcel, our conscious representations of what we perceive often differ qualitatively from our nonconscious representations of sensory stimuli. Outside of conscious awareness, we continually try to make sense of a constant flow of sensory information. Also outside of awareness are perceptual hypotheses regarding how the current sensory information matches with various properties and objects we have encountered previously in our environment. These hypotheses are inferences based on knowledge stored in long-term memory. During the matching process, information from differing sensory modalities is integrated.

According to Marcel’s model, once there is a suitable match between the sensory data and the perceptual hypotheses regarding various properties and objects, the match is reported to conscious awareness as “being” particular properties and objects. Consciously, we are aware only of the reported objects or properties; we are not aware of the sensory data, the perceptual hypotheses that do not lead to a match, or even the processes that govern the reported match. Thus, before a given object or property is detected consciously (i.e., is reported to conscious awareness by the nonconscious matching process), we will have chosen a satisfactory perceptual hypothesis and excluded various possibilities that less satisfactorily matched the incoming sensory data to what we already know or can infer.

According to Marcel’s model, the sensory data and the perceptual hypotheses are available to and used by various nonconscious cognitive processes in addition to the matching process. Sensory data and cognitive processes that do not reach awareness
still exert influence on how we think and how we perform other cognitive tasks. It is widely held that we have limited attentional capacity (e.g., see Norman, 1976). According to Marcel, we accommodate these limitations by making use of nonconscious information and processes as much as possible, while limiting the information and processing that enter our conscious awareness. In this way, our limited attentional capacity is not constantly overtaxed. Hence, our processes of attention are intimately intertwined with our processes of perception. In this chapter, we have described many functions and processes of attention. In the following chapter, we focus on various aspects of perception.

The study of attention and consciousness highlights several key themes in cognitive psychology, as described in Chapter 1.

The first theme is the respective roles of structures and processes. The brain contains various structures and systems of structures, such as the reticular activating system, that generate the processes that contribute to attention. Sometimes, the relationship between structure and process is not entirely clear, and it is the job of cognitive psychologists to better understand it. For example, blindsight is a phenomenon in which a process occurs—sight—in the absence of the structures in the brain that would seem to be necessary for the sight to take place.

A second theme is the relation between biology and behavior. Blindsight is a case of a curious and as yet poorly understood link. The biology does not appear to be there to generate the behavior. Another interesting example is attention deficit hyperactivity disorder. Physicians now have available a number of drugs that treat ADHD. These treatments enable children as well as adults better to focus on tasks that they need to get done. But the mechanisms by which the drugs work are still poorly understood. Indeed, somewhat paradoxically, most of the drugs used to treat ADHD are stimulants, which, when given to children with ADHD, appear to calm them down.

A third theme is validity of causal inference versus ecological validity. Where should one study, say, vigilance? One can study it in a laboratory, of course, to achieve careful experimental control. But if one is studying high-stakes vigilance situations, such as those in which military officers are examining radar screens for possible attacks against the country, one must insist on having a high degree of ecological validity to ensure that the results apply to the actual situation in which the military officers find themselves. The stakes are too high to allow slippage. Yet, when one studies vigilance in the actual-life situation, one cannot and would not want to make attacks against the country happen. So one needs simulations that are as realistic as possible. In this way, one tries to ensure ecological validity of conclusions drawn.

Get two friends to help you with this demonstration. Ask one friend to read something very softly into your other friend’s ear (it can be anything—a joke, a greeting card, or a cognitive psychology textbook), and have your other friend try to “shadow” what the other friend is saying. (Shadowing is repeating all the words that another person is saying.) In your friend’s other ear, say “animal” very softly. Later, ask your friend what you said. Most likely, your friend will not be able to identify what you said. Try this again, but this time say your friend’s name. Your friend will most likely be able to recall that you said his or her name. This demonstrates Triesman’s attenuation model.
Summary

1. Can we actively process information even if we are not aware of doing so? If so, what do we do, and how do we do it? Whereas attention embraces all the information that an individual is manipulating (a portion of the information available from memory, sensation, and other cognitive processes), consciousness comprises only the narrower range of information that the individual is aware of manipulating. Attention allows us to use our limited active cognitive resources (e.g., because of the limits of working memory) judiciously, to respond quickly and accurately to interesting stimuli, and to remember salient information.

Conscious awareness allows us to monitor our interactions with the environment, to link our past and present experiences and thereby sense a continuous thread of experience, and to control and plan for future actions.

We actively can process information at the preconscious level without being aware of doing so. For example, researchers have studied the phenomenon of priming, in which a given stimulus increases the likelihood that a subsequent related (or identical) stimulus will be readily processed (e.g., retrieval from long-term memory). In contrast, in the tip-of-the-tongue phenomenon, another example of preconscious processing, retrieval of desired information from memory does not occur, despite an ability to retrieve related information.

Cognitive psychologists also observe distinctions in conscious versus preconscious attention by distinguishing between controlled and automatic processing in task performance. Controlled processes are relatively slow, sequential in nature, intentional (requiring effort), and under conscious control. Automatic processes are relatively fast, parallel in nature, and for the most part outside of conscious awareness. Actually, a continuum of processing appears to exist, from fully automatic to fully controlled processes. Two automatic processes that support our attentional system are habituation and dishabituation, which affect our responses to familiar versus novel stimuli.

2. What are some of the functions of attention? One main function involved in attention is identifying important objects and events in the environment. Researchers use measures from signal-detection theory to determine an observer’s sensitivity to targets in various tasks. For example, vigilance refers to a person’s ability to attend to a field of stimulation over a prolonged period, usually with the stimulus to be detected occurring only infrequently. Whereas vigilance involves passively waiting for an event to occur, search involves actively seeking out a stimulus.

People use selective attention to track one message and simultaneously to ignore others. Auditory selective attention (such as in the cocktail party problem) may be observed by asking participants to shadow information presented dichotically. Visual selective attention may be observed in tasks involving the Stroop effect. Attentional processes also are involved during divided attention, when people attempt to handle more than one task at once; generally, the simultaneous performance of more than one automatized task is easier to handle than the simultaneous performance of more than one controlled task. However, with practice, individuals appear to be capable of handling more than one controlled task at a time, even engaging in tasks requiring comprehension and decision making.

3. What are some of the theories cognitive psychologists have developed to explain what they have observed about attentional processes? Some theories of attention involve an attentional filter or bottleneck, according to which information is selectively blocked out or attenuated as it passes from one level of processing to the next. Of the bottleneck theories, some suggest that the signal-blocking or signal-attenuating mechanism occurs just after sensation and prior to any perceptual processing; others propose a later mechanism, after at least some perceptual processing has...
Attentional-resource theories offer an alternative way of explaining attention; according to these theories, people have a fixed amount of attentional resources (perhaps modulated by sensory modalities) that they allocate according to the perceived task requirements. Resource theories and bottleneck theories actually may be complementary. In addition to these general theories of attention, some task-specific theories (e.g., feature-integration theory, guided-search theory, and similarity theory) have attempted to explain search phenomena in particular.

4. What have cognitive psychologists learned about attention by studying the human brain? Early neuropsychological research led to the discovery of feature detectors, and subsequent work has explored other aspects of feature detection and integration processes that may be involved in visual search. In addition, extensive research on attentional processes in the brain seems to suggest that the attentional system primarily involves two regions of the cortex, as well as the thalamus and some other subcortical structures; the attentional system also governs various specific processes that occur in many areas of the brain, particularly in the cerebral cortex. Attentional processes may be a result of heightened activation in some areas of the brain, of inhibited activity in other areas of the brain, or perhaps of some combination of activation and inhibition. Studies of responsivity to particular stimuli show that even when an individual is focused on a primary task and is not consciously aware of processing other stimuli, the brain of the individual automatically responds to infrequent, deviant stimuli (e.g., an odd tone). By using various approaches to the study of the brain (e.g., PET, ERP, lesion studies, and psychopharmacological studies), researchers are gaining insight into diverse aspects of the brain and also are able to use converging operations to begin to explain some of the phenomena they observe.

Thinking about Thinking: Factual, Analytical, Creative, and Practical Questions

1. Describe some of the evidence regarding the phenomena of priming and preconscious perception.
2. Why are habituation and dishabituation of particular interest to cognitive psychologists?
3. Compare and contrast the theories of visual search described in this chapter.
4. Choose one of the theories of attention and explain how the evidence from signal detection, selective attention, or divided attention supports or challenges the theory you chose.
5. Design one task likely to activate the posterior attentional system and another task likely to activate the anterior attentional system.
6. Design an experiment for studying divided attention.
7. Describe some practical ways in which you can use forcing functions and other strategies for lessening the likelihood that automatic processes will have negative consequences for you in some of the situations you face.
8. How could advertisers use some of the principles of visual search or selective attention to increase the likelihood that people will notice their messages?
Key Terms

arousal
attention
automatic processes
automatization
binaural presentation
blindsight
change blindness
cocktail party problem
conjunction search
consciousness
controlled processes
dichotic presentation
dishabituation
distracters
divided attention
feature-integration theory
feature search
habituation
multimode theory
priming
search
selective attention
sensory adaptation
signal
signal detection
signal-detection theory (SDT)
Stroop effect
tip-of-the-tongue phenomenon
vigilance

CogLab

To learn more, examine the following experiments:
Prototypes
Absolute Identification
Implicit Learning

Annotated Suggested Readings


Cognitive Psychology

Robert J. Sternberg
Tufts University

with contributions of the
Investigating Cognitive Psychology boxes by

Jeff Mio
California State University–Pomona
How do you know the answers to the preceding questions, or to any questions for that matter? How do you remember any of the information you use every waking hour of every day? Memory is the means by which we retain and draw on our past experiences to use that information in the present (Tulving, 2000b; Tulving & Craik, 2000). As a process, memory refers to the dynamic mechanisms associated with storing, retaining, and retrieving information about past experience (Bjorklund, Schneider, & Hernández Blasi, 2003; Crowder, 1976). Specifically, cognitive psychologists have identified three common operations of memory: encoding, storage, and retrieval (Baddeley, 1998, 1999, 2000b; Brown & Craik, 2000). Each operation represents a stage in memory processing. In encoding, you transform sensory data into a form of mental representation. In storage, you keep encoded information in memory. In retrieval, you pull out or use information stored in memory. These memory processes are discussed at length in Chapter 6.

This chapter introduces some of the tasks used for studying memory. It then discusses the traditional model of memory. This model includes the sensory, short-term, and long-term storage systems. Although this model still influences current thinking about memory, we consider some interesting alternative perspectives and models of memory before moving on to discuss exceptional memory and insights provided by neuropsychology.

**Tasks Used for Measuring Memory**

In studying memory, researchers have devised various tasks that require participants to remember arbitrary information (e.g., numerals or letter strings) in different ways. Because this chapter includes many references to these tasks, we begin this section with an advance organizer—a basis for organizing the information to be given. In this way, you will know how memory is studied. The tasks described in the following section involve recall versus recognition memory and implicit versus explicit memory.
Recall versus Recognition Tasks

In **recall**, you produce a fact, a word, or other item from memory. Fill-in-the-blank and most essay tests require that you recall items from memory. In **recognition**, you select or otherwise identify an item as being one that you learned previously. (See Table 5.1 for examples and explanations of each type of task.) Multiple-choice and true-false tests involve some degree of recognition. Three main types of recall tasks are used in experiments (Lockhart, 2000). The first is **serial recall**, in which you recall items in the exact order in which they were presented (Crowder & Green, 2000). The second is **free recall**, in which you recall items in any order you choose. The third is **cued recall**, in which you are first shown items in pairs, but during recall you are cued with only one member of each pair and are asked to recall each mate. Cued recall is also called “paired-associates recall” (Lockhart, 2000). Psychologists also can measure **relearning**, which is the number of trials it takes to learn once again items that were learned at some time in the past. Relearning has also been referred to as savings and can be observed in adults, children, and animals (Bauer, 2005; Lynne, Yukako, &

### TABLE 5.1 Types of Tasks Used for Measuring Memory

Some memory tasks involve recall or recognition of explicit memory for declarative knowledge. Other tasks involve implicit memory and memory for procedural knowledge.

<table>
<thead>
<tr>
<th>Tasks Requiring Explicit Memory for Declarative Knowledge</th>
<th>Description of What the Tasks Require</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Explicit-memory tasks</td>
<td>You must consciously recall particular information.</td>
<td>Who wrote Hamlet?</td>
</tr>
<tr>
<td>Declarative-knowledge tasks</td>
<td>You must recall facts.</td>
<td>What is your first name?</td>
</tr>
<tr>
<td>Recall tasks</td>
<td>You must produce a fact, a word, or other item from memory.</td>
<td>Fill-in-the-blank tests require that you recall items from memory. For example, “The term for persons who suffer severe memory impairment is ______.”</td>
</tr>
<tr>
<td>Serial-recall task</td>
<td>You must repeat the items in a list in the exact order in which you heard or read them.</td>
<td>If you were shown the digits 2-8-7-1-6-4, you would be expected to repeat “2-8-7-1-6-4,” in exactly that order.</td>
</tr>
<tr>
<td>Free-recall task</td>
<td>You must repeat the items in a list in any order in which you can recall them.</td>
<td>If you were presented with the word list “dog, pencil, time, hair, monkey, restaurant,” you would receive full credit if you repeated “monkey, restaurant, dog, pencil, time, hair.”</td>
</tr>
<tr>
<td>Cued-recall task</td>
<td>You must memorize a list of paired items; then when you are given one item in the pair, you must recall the mate for that item.</td>
<td>Suppose that you were given the following list of pairs: “time-city, mist-home, switch-paper, credit-day, fist-cloud, number-branch.” Later, when you were given the stimulus “switch,” you would be expected to say “paper,” and so on.</td>
</tr>
</tbody>
</table>
McKinney, 2002; Monk & associates, 1996). The relearning effect was also observed in fetal rats. These rats demonstrated shorter learning times for motor movements they had previously learned (Robinson, 2005). This effect is clearly extensively generalizable to many situations and participants.

Recognition memory is usually much better than recall (although there are some exceptions, which are discussed in Chapter 6). For example, in one study, participants could recognize close to 2000 pictures in a recognition-memory task (Standing, Conezio, & Haber, 1970). It is difficult to imagine anyone recalling 2000 items of any kind they were just asked to memorize. As you will see later in the section on exceptional memory, even with extensive training the best measured recall performance is around 80 items.

Informing participants of the type of future test can influence the amount of learning that occurs. Specifically, recall tasks generally elicit deeper levels of information processing than recognition ones. Imagine studying for an exam. You will likely, when preparing for an essay exam, aim to relate concepts to one another. However, when preparing for a multiple-choice exam, you will likely try to remember facts. It

<table>
<thead>
<tr>
<th>TABLE 5.1</th>
<th>Types of Tasks Used for Measuring Memory (cont.)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Tasks Requiring Explicit Memory for Declarative Knowledge</strong></td>
<td><strong>Description of What the Tasks Require</strong></td>
</tr>
<tr>
<td>Recognition tasks</td>
<td>You must select or otherwise identify an item as being one that you learned previously.</td>
</tr>
<tr>
<td>Implicit-memory tasks</td>
<td>You must draw on information in memory without consciously realizing that you are doing so.</td>
</tr>
<tr>
<td>Tasks involving procedural knowledge</td>
<td>You must remember learned skills and automatic behaviors, rather than facts.</td>
</tr>
</tbody>
</table>
is likely that, after studying for the essay exam, you would remember more details about the information. As mentioned before, the essay exam resembles the recall task and the multiple-choice exam resembles the recognition task, although of course they are not identical. Some psychologists refer to recognition-memory tasks as tapping receptive knowledge. Recall memory tasks, in which you have to produce an answer, instead require expressive knowledge. Differences between receptive and expressive knowledge also are observed in areas other than that of simple memory tasks (e.g., language, intelligence, and cognitive development).

**Implicit versus Explicit Memory Tasks**

Memory theorists distinguish between explicit memory and implicit memory (Mulligan, 2003). Each of the tasks previously discussed involves explicit memory, in which participants engage in conscious recollection. For example, they might recall or recognize words, facts, or pictures from a particular prior set of items. A related phenomenon is implicit memory, in which we use information but are not consciously aware that we are doing so (McBride, 2007; Roediger & McDermott, 1993; Schacter, 1995a, 2000; Schacter, Chiu, & Ochsner, 1993; Schacter & Graf, 1986a, 1986b). Every day you engage in many tasks that involve your unconscious recollection of information. Even as you read this book, you unconsciously are remembering various things. They include the meanings of particular words, some of the cognitive-psychological concepts you read about in earlier chapters, and even how to read. These recollections are aided by implicit memory. There are differences in explicit memory over the life span; however, implicit memory does not show the same changes. Specifically, infants and older adults often tend to have relatively poor explicit memory but implicit memory that is comparable to that of young adults (Carver & Bauer, 2001; Murphy, McKone, & Slee, 2003). In certain patient groups you also see differences in explicit memory with spared implicit memory; these groups will be discussed later in the chapter.

In the laboratory, implicit memory is sometimes examined by having people perform word-completion tasks. In a word-completion task, participants receive a word fragment, such as the first three letters of a word. They then complete it with the first word that comes to mind. For example, suppose that you are asked to fill in the blanks with the five missing letters to form a word: imp_ _ _ _ _. Because you recently have seen the word implicit, you would be more likely to provide the five letters “l-i-c-i-t” for the blanks than would someone who had not recently been exposed to the word. You have been primed. Priming is the facilitation of your ability to utilize missing information. In general, participants perform better when they have seen the word on a recently presented list, although they have not been explicitly instructed to remember words from that list (Tulving, 2000a). Priming even works in situations where you are not aware that you have seen the word before—that is, if the word was presented for a fraction of a second or in some other degraded form.

Procedural memory, or memory for processes, is a subtype of nondeclarative memory (Tulving, 1985). Examples of procedural memory include the procedures involved in riding a bike or driving a car. Consider when you drive to the mall: You probably put the car into gear, use your blinkers, and stay in your lane without actively thinking about the task. Nor do you need consciously to remember what you should do at a red

Copyright 2009 Cengage Learning, Inc. All Rights Reserved. May not be copied, scanned, or duplicated, in whole or in part.
light. Many of the activities that we do every day fall under the purview of procedural memory; these can range from brushing your teeth to writing a paper.

The cerebellum of the brain seems to be centrally involved in procedural memory. The neuropsychological and cognitive evidence supporting a discrete procedural memory has been quite well documented (Cohen & associates, 1985; Cohen & Squire, 1980; Rempel-Clower & associates, 1996; Squire, 1987; Squire, Knowlton, & Musen, 1993). In the laboratory, procedural memory is frequently examined with the rotary-pursuit task. The rotary-pursuit task requires participants to maintain contact between an L-shaped stylus and a small rotating disk (Costello, 1967). The disk is generally the size of a nickel, less than an inch in diameter. This disk is placed on a quickly rotating platform. The participant must track the small disk with the wand as it quickly spins around on a platform. After learning with a specific disk and speed of rotation, participants are asked to complete the task again, either with the same disk and the same speed or with a new disk or speed. Verdolini-Marston and Balota (1994) noted that when a new disk or speed is used, participants do relatively poorly. But with the same disk and speed, participants do as well as they had after learning the task, even if they don’t remember previously completing the task.

Another task used to examine procedural memory is mirror tracing. In the mirror-tracing task, a plate with the outline of a shape drawn on it is put behind a barrier where it cannot be seen. Beyond the barrier in the participant’s line of sight is a mirror. When the participant reaches around the barrier, his or her hand and the plate with the shape are within view. Participants then take a stylus and trace the outline of the shape drawn on the plate. When first learning this task, participants have difficulty staying on the shape. Typically, there are many points at which the stylus leaves the outline. Moreover, it takes a relatively long time to trace the entire shape. With practice, however, participants become quite efficient and accurate with this task. Participants’ retention of this skill gives us a way to study procedural memory (Gabrieli & associates, 1997; Rodrigue, Kennedy, & Raz, 2005).

The methods for measuring both implicit and explicit memory described here and in Table 5.1 assume that implicit and explicit memory are separate and can be measured by different tasks. Some researchers have challenged this assumption. Instead, they assume that implicit and explicit memory both play a role in every response, even if the task at hand is intended to measure only one type of memory. Thus, cognitive psychologists have developed models that assume that both implicit and explicit memory influence almost all responses.

One of the first and most widely recognized models in this area is the process-dissociation model (Jacoby, 1991). The model assumes that implicit and explicit memory both have a role in virtually every response. Thus, only one task is needed to measure both these processes. However, two different tasks can be used within the process-dissociation framework.

In one of these tasks, participants learn a list of words and are then presented with word fragments. At this point, they are given either inclusive instructions, in which they are to use the information they previously learned to complete the words; or the instructions are exclusive, in which the participant is told not to use the items from the previous list to fill in the word fragments. By subtracting the number of times that a word from the list is used in the exclusion condition from the same event in the inclusion condition Jacoby was able to estimate the effect of explicit memory. A few more
steps allowed Jacoby to estimate implicit memory on the same task. The process-dissociation task has been used extensively (Memon, Holliday, & Hill, 2006; Yonelinas, 2001). However, this procedure is not without criticisms. These criticisms include that process dissociation produces biased estimates when guessing occurs and when participants use a strategy that involves evaluating and second guessing their responses (McBride & Dosher, 2002; McKenzie & Tiberghien, 2004; Yu & Bellezza, 2000).

Traditional Model of Memory

There are several different major models of memory (Murdock, 2003; Roediger, 1980b). In the mid-1960s, based on the data available at the time, researchers proposed a model of memory distinguishing two structures of memory first proposed by William James (1890/1970): primary memory, which holds temporary information currently in use, and secondary memory, which holds information permanently or at least for a very long time (Waugh & Norman, 1965). Three years later, Richard Atkinson and Richard Shiffrin (1968) proposed an alternative model that conceptualized memory in terms of three memory stores: (1) a sensory store, capable of storing relatively limited amounts of information for very brief periods; (2) a short-term store, capable of storing information for somewhat longer periods but also of relatively limited capacity; and (3) a long-term store, of very large capacity, capable of storing information for very long periods, perhaps even indefinitely (Richardson-Klavehn & Bjork, 2003).

The model differentiates among structures for holding information, termed stores, and the information stored in the structures, termed memory. Today, however, cognitive psychologists commonly describe the three stores as sensory memory, short-term memory, and long-term memory. Also, Atkinson and Shiffrin were not suggesting that the three stores are distinct physiological structures. Rather, the stores are hypothetical constructs—concepts that are not themselves directly measurable or observable but that serve as mental models for understanding how a psychological phenomenon works. Figure 5.1 shows a simple information-processing model of these stores (Atkinson & Shiffrin, 1971). As this figure shows, the Atkinson-Shiffrin model emphasizes the passive receptacles in which memories are stored. But it also alludes to some control processes that govern the transfer of information from one store to another.

The three-store model is, however, not the only way to conceptualize memory. The following sections first present what we know about memory in terms of the three-store model. Then some alternative ways in which to conceptualize memory are described. Let’s begin with the sensory store in the three-store model.

Sensory Store

The sensory store is the initial repository of much information that eventually enters the short- and long-term stores. Strong (although not undisputed; see Haber, 1983) evidence argues in favor of the existence of an iconic store. The iconic store is a discrete visual sensory register that holds information for very short periods. Its name derives from the fact that information is stored in the form of icons. These in turn are
visual images that represent something. Icons usually resemble whatever is being represented.

If you have ever “written” your name with a lighted sparkler (or stick of incense) against a dark background, you have experienced the persistence of a visual memory. You briefly “see” your name, although the sparkler leaves no physical trace. This visual persistence is an example of the type of information held in the iconic store.

**Sperling’s Discovery**
The initial discovery regarding the existence of the iconic store came from a doctoral dissertation by a graduate student at Harvard named George Sperling (1960). He addressed the question of how much information we can encode in a single, brief glance at a set of stimuli. Sperling flashed an array of letters and numbers on a screen for a mere 50 milliseconds (thousandths of a second). Participants were asked to report the identity and location of as many of the symbols as they could recall. Sperling could be sure that participants got only one glance because previous research had shown that 0.050 seconds is long enough for only a single glance at the presented stimulus.

Sperling found that when participants were asked to report on what they saw, they remembered only about four symbols. The finding confirmed an earlier one made by Brigden in 1933. The number of symbols recalled was pretty much the same, without regard to how many symbols had been in the visual display. Some of Sperling’s participants mentioned that they had seen all the stimuli clearly. But while reporting what they saw, they forgot the other stimuli. Sperling then conceived an ingenious idea for how to measure what the participants saw. The procedure used by Brigden and in the first set of studies by Sperling is a whole-report
procedure. In this procedure, participants report every symbol they have seen. Sperling then introduced a partial-report procedure. Here, participants need to report only part of what they see.

Sperling found a way to obtain a sample of his participants’ knowledge. He then extrapolated from this sample to estimate their total knowledge. His logic was similar to that of school examinations, which also are used as samples of an individual’s total knowledge of course material. Sperling presented symbols in three rows of four symbols each. Figure 5.2 shows a display similar to one that Sperling’s participants might have seen. Sperling informed participants that they would have to recall only a single row of the display. The row to be recalled was signaled by a tone of high, medium, or low pitch. The pitches corresponded to the need to recall the top, middle, or bottom row, respectively.

To estimate the duration of iconic memory, Sperling manipulated the interval between the display and the tone. The range of the interval was from 0.10 seconds before the onset of the display to 1.0 second after the offset of the display. The partial-report procedure dramatically changed how much participants could recall. Sperling then multiplied the number of symbols recalled with this procedure by three. The reason was that participants had to recall only one third of the information presented but did not know beforehand which of the three lines they would be asked to report.

Using this partial-report procedure, Sperling found that participants had available roughly 9 of the 12 symbols if they were cued immediately before or immediately after the appearance of the display. However, when they were cued 1 second later, their recall was down to 4 or 5 of the 12 items. This level of recall was about the same as that obtained through the whole-report procedure. These data suggest that the iconic store can hold about 9 items. They also suggest that information in this store decays very rapidly (Figure 5.3). Indeed, the advantage of the partial-report procedure

---

**FIGURE 5.2**

This symbolic display is similar to the one used for George Sperling’s visual-recall task. From Psychology, Second Edition by Margaret W. Matlin, copyright © 1995 by Holt, Rinehart and Winston. Reproduced by permission of the publisher.
is reduced drastically by 0.3 seconds of delay. It essentially is obliterated by 1 second of delay for onset of the tone.

Sperling’s results suggest that information fades rapidly from iconic storage. Why are we subjectively unaware of such a fading phenomenon? First, we rarely are subjected to stimuli such as the ones in his experiment. They appeared for only 50 milliseconds and then disappeared before participants needed to recall them. Second and more important, however, we are unable to distinguish what we see in iconic memory from what we actually see in the environment. What we see in iconic memory is what we take to be in the environment. Participants in Sperling’s experiment generally reported that they could still see the display up to 150 milliseconds after it actually had been terminated.

Elegant as it was, Sperling’s use of the partial-report procedure was imperfect. It still suffered, at least to some small extent, from the problem inherent in the full-report procedure: Participants had to report multiple symbols. They may have experienced fading of memory during the report. Indeed, a distinct possibility of output interference exists. In this case, the production of output interferes with the phenomenon being studied. That is, verbally reporting multiple symbols may interfere with reports of iconic memory.

The figure shows the average number of letters recalled (left axis; percentage equivalents indicated on right axis) by a subject, based on using the partial-report procedure, as a function of the delay between the presentation of the letters and the tone signaling when to demonstrate recall. The bar at the lower-right corner indicates the average number of letters recalled when subjects used the whole-report procedure. (After Sperling, 1960.)
Subsequent Refinement
In subsequent work, participants were shown displays of two rows of eight randomly chosen letters for a duration of 50 milliseconds (Averbach & Coriell, 1961). In this investigation, a small mark appeared just above one of the positions where a letter had appeared (or was about to appear). Its appearance was at varying time intervals before or after presentation of the letters. In this research, then, participants needed to report only a single letter at a time. The procedure thus minimized output interference. These investigators found that when the bar appeared immediately before or after the stimulus display, participants could report accurately on about 75% of the trials. Thus, they seemed to be holding about 12 items (75% of 16) in sensory memory. Sperling’s estimate of the capacity of iconic memory, therefore, may have been conservative. The evidence in this study suggests that when output interference is greatly reduced, the estimates of the capacity of iconic memory may greatly increase. Iconic memory may comprise as many as 12 items.

A second experiment (Averbach & Coriell, 1961) revealed an additional important characteristic of iconic memory: It can be erased. The erasable nature of iconic memory definitely makes our visual sensations more sensible. We would be in serious trouble if everything we saw in our visual environment persisted for too long. For example, if we are scanning the environment at a rapid pace, we need the visual information to disappear quickly.

The investigators found that when a stimulus was presented after a target letter in the same position that the target letter had occupied, it could erase the visual icon (Averbach & Coriell, 1961). This interference is called backward visual masking. Backward visual masking is mental erasure of a stimulus caused by the placement of one stimulus where another one had appeared previously. If the mask stimulus is presented in the same location as a letter and within 100 milliseconds of the presentation of the letter, the mask is superimposed on the letter. For example, F followed by L would be E. At longer intervals between the target and the mask, the mask erases the original stimulus. For example, only the L would remain if F and then L had been presented. At still longer intervals between the target and the mask, the mask no longer interferes. This noninterference is presumably because the target information already has been transferred to more durable memory storage.

To summarize, visual information appears to enter our memory system through an iconic store. This store holds visual information for very short periods. In the normal course of events, this information may be transferred to another store. Or it may be erased. Erasure occurs if other information is superimposed on it before there is sufficient time for the transfer of the information to another memory store. Erasure or movement into another store also occurs with auditory information that is in echoic memory.

Short-Term Store
Most of us have little or no introspective access to our sensory memory stores. Nevertheless, we all have access to our short-term memory store. It holds memories for matters of seconds and, occasionally, up to a couple of minutes. For example, can you remember the name of the researcher who discovered the iconic store? What about the names of the researchers who subsequently refined this work? If you can recall
those names, you used some memory-control processes for doing so. According to the Atkinson-Shiffrin model, the short-term store holds not only a few items. It also has available some control processes that regulate the flow of information to and from the long-term store. Here, we may hold information for longer periods. Typically, material remains in the short-term store for about 30 seconds, unless it is rehearsed to retain it. Information is stored acoustically (by the way it sounds) rather than visually (by the way it looks).

How many items of information can we hold in short-term memory at any one time? In general, our immediate (short-term) memory capacity for a wide range of items appears to be about seven items, plus or minus two (Miller, 1956). An item can be something simple, such as a digit, or something more complex, such as a word. If we chunk together a string of, say, 20 letters or numbers into 7 meaningful items, we can remember them. We could not, however, remember 20 items and repeat them immediately. For example, most of us cannot hold in short-term memory this string of 21 numbers: 101001000100001000100. Suppose, however, we chunk it into larger units, such as 10, 100, 1000, 10000, 1000, and 100. We probably will be able to reproduce easily the 21 numerals as 6 items (Miller, 1956).

Other factors also influence the capacity for temporary storage in memory. For example, the number of syllables we pronounce with each item affects the number of items we can recall. When each item has a larger number of syllables, we can recall fewer items (Baddeley, Thomson, & Buchanan, 1975; Naveh-Benjamin & Ayres, 1986; Schweickert & Boruff, 1986). In addition, any delay or interference can cause our seven-item capacity to drop to about three items. Indeed, in general the capacity limit may be closer to three to five than it is to seven (Cowan, 2001). Some estimates are even lower (e.g., Waugh & Norman, 1965).

Most studies have used verbal stimuli to test the capacity of the short-term store, but people can also hold visual information in short-term memory. For example, they can hold information about shapes as well as their colors and orientations. What is the capacity of the short-term store of visual information? Is it less, the same, or perhaps greater? A team of investigators set out to discover the capacity of the short-term store for visual information (Luck & Vogel, 1997; Vogel, Woodman, & Luck, 2001). They presented experimental participants with two visual displays. The displays were presented in sequence, one following the other. The stimuli were of three types: colored squares, black lines at varying orientations, and colored lines at different orientations. Thus, the third kind of stimulus combined the features of the first two. The kind of stimulus was the same in each of the two displays. For example, if the first display contained colored squares, so did the second. The two displays could be either the same or different from each other. If they were different, then it was by only one feature. The participants needed to indicate whether the two displays were the same or different from each other. The investigators found that participants could hold roughly four items in memory, within the estimates suggested by Cowan (2001). The results were the same whether just individual features were varied (i.e., colored squares, black lines at varying orientation) or pairs of features were varied (i.e., colored lines at different orientations). Thus, storage seems to depend on numbers of objects rather than numbers of features.

This work contained a possible confound (i.e., other responsible factor that cannot be easily disentangled from the supposed causal factor). In the stimuli with colored lines
at different orientations, the added feature was at the same spatial location as the original one. That is, color and orientation were, with respect to the same object, in the same place in the display. A further study thus was done to separate the effects of spatial location from number of objects (Lee & Chun, 2001). In this research, stimuli comprising boxes and lines could be either at separate locations or at overlapping locations. The overlapping locations thus separated the objects from the fixed locations. The research would enable one to determine whether people can remember four objects, as suggested in the previous work, or four spatial locations. The results were the same as in the earlier research. Participants still could remember four objects, regardless of spatial locations. Therefore, memory was for objects, not spatial locations. Further, using American Sign Language, researchers have found that short-term memory can hold approximately four items for signed letters. This finding is consistent with earlier work on visual-spatial short-term memory. The finding makes sense, given the visual nature of these items (Bavelier & associates, 2006; Wilson & Emmorey, 2006).

**Long-Term Store**

We constantly use short-term memory throughout our daily activities. When most of us talk about memory, however, we usually are talking about long-term memory. Here we keep memories that stay with us over long periods, perhaps indefinitely. All of us rely heavily on our long-term memory. We hold in it information we need to get us by in our day-to-day lives. Examples are what people’s names are, where we keep things, how we schedule ourselves on different days, and so on. We also worry when we fear that our long-term memory is not up to snuff.

How much information can we hold in long-term memory? How long does the information last? The question of storage capacity can be disposed of quickly because the answer is simple. We do not know. Nor do we know how we would find out. We can design experiments to tax the limits of short-term memory. But we do not know how to test the limits of long-term memory and thereby find out its capacity. Some theorists have suggested that the capacity of long-term memory is infinite, at least in practical terms (Bahrick, 1984a, 1984b, 2000; Bahrick & Hall, 1991; Hintzman, 1978). It turns out that the question of how long information lasts in long-term memory is not easily answerable. At present, we have no proof even that there is an absolute outer limit to how long information can be stored.

What is stored in the brain? Wilder Penfield addressed this question while performing operations on the brains of conscious patients afflicted with epilepsy. He used electrical stimulation of various parts of the cerebral cortex to locate the origins of each patient’s problem. In fact, his work was instrumental in plotting the motor and sensory areas of the cortex described in Chapter 2 of this text.

During the course of such stimulation, Penfield (1955, 1969) found that patients sometimes would appear to recall memories from way back in their childhoods. These memories may not have been called to mind for many, many years. (Note that the patients could be stimulated to recall episodes such as events from their childhood, not facts such as the names of U.S. presidents.) These data suggested to Penfield that long-term memories might be permanent.

Some researchers have disputed Penfield’s interpretations (e.g., Loftus & Loftus, 1980). For example, they have noted the small number of such reports in relation to
the hundreds of patients on whom Penfield operated. In addition, we cannot be cer-
tain that the patients actually were recalling these events. They may have been in-
venting them. Other researchers, using empirical techniques on older participants,
found contradictory evidence.

Some researchers tested participants’ memory for names and photographs of their
high-school classmates (Bahrick, Bahrick, & Wittlinger, 1975). Even after 25 years,
there was little forgetting of some aspects of memory. Participants tended to recognize
names as belonging to classmates rather than to outsiders. Recognition memory for
matching names to graduation photos was quite high. As you might expect, recall of
names showed a higher rate of forgetting. The term permastore refers to the very long-
term storage of information, such as knowledge of a foreign language (Bahrick, 1984a,
1984b; Bahrick & associates, 1993) and of mathematics (Bahrick & Hall, 1991).

Schmidt and associates (2000) studied the permastore effect for names of streets
near one’s childhood homes. Indeed, I just returned to my childhood home of more
than 40 years ago and perfectly remembered the names of the nearby streets. These
findings indicate that permastore can occur even for information that you have pas-
sively learned. Some researchers have suggested that permastore is a separate memory
system. Others, such as Neisser (1999), have argued that one long-term memory sys-
tem can account for both. There is to date no resolution of the issue.

The Levels-of-Processing Model

A radical departure from the three-stores model of memory is the levels-of-processing
framework, which postulates that memory does not comprise three or even any spe-
cific number of separate stores but rather varies along a continuous dimension in
terms of depth of encoding (Craik & Lockhart, 1972). In other words, there are
theoretically an infinite number of levels of processing (LOP) at which items can be
encoded. There are no distinct boundaries between one level and the next. The em-
phasis in this model is on processing as the key to storage. The level at which infor-
mation is stored will depend, in large part, on how it is encoded. Moreover, the deeper
the level of processing, the higher, in general, is the probability that an item may be
retrieved (Craik & Brown, 2000).

A set of experiments seemed to support the LOP view (Craik & Tulving, 1975).
Participants received a list of words. A question preceded each word. Questions were
varied to encourage three different levels of processing. In progressive order of depth,
they were physical, phonological, and semantic. Samples of the words and the questions
are shown in Table 5.2. The results of the research were clear. The deeper the level
of processing encouraged by the question, the higher the level of recall achieved.
Similar results emerged independently in Russia (Zinchenko, 1962, 1981). Words
that were logically (e.g., taxonomically) connected (e.g., dog and animal) were re-
called more easily than were words that were concretely connected (e.g., dog and leg).
At the same time, concretely connected words were more easily recalled than were
words that were unconnected.

The levels-of-processing framework can also be applied to nonverbal stimuli. Melinda
Burgess and George Weaver (2003) noted that faces that were deeply pro-
cessed were better recognized on a subsequent test than those that were studied at a lower level of processing. A level-of-processing (or depth-of-processing) benefit can be seen for a variety of populations, including in patients with schizophrenia (Ragland & associates, 2003).

An even more powerful inducement to recall has been termed the self-reference effect (Rogers, Kuiper, & Kirker, 1977). In the self-reference effect, participants show very high levels of recall when asked to relate words meaningfully to themselves by determining whether the words describe them. Even the words that participants assess as not describing themselves are recalled at high levels. This high recall is a result of considering whether the words do or do not describe the participants. However, the highest levels of recall occur with words that people consider self-descriptive. Similar self-reference effects have been found by many other researchers (e.g., Bower & Gilligan, 1979; Brown, Keenan, & Potts, 1986; Ganellen & Carver, 1985; Halpin & associates, 1984; Katz, 1987; Reeder, McCormick, & Esselman, 1987).

Surprisingly, the type of information that is being learned can influence the self-reference effect. When comparing positive and negative traits, investigators found the self-reference effect for the positive but not the negative traits (D'Argembeau, Comblain, & Van der Linden, 2005). Thus, we are better able to associate positive than negative descriptors with ourselves.

Some researchers suggest that the self-reference effect is distinctive, but others suggest that it is explained easily in terms of the LOP framework or other ordinary memory processes (e.g., Mills, 1983). Specifically, each of us has a very elaborate self-schema. This self-schema is an organized system of internal cues regarding our attributes, our personal experiences, and ourselves. Thus, we can richly and elaborately encode information related to ourselves much more so than information about other topics (Bellezza, 1984, 1992). Also, we easily can organize new information pertaining to ourselves. When other information is also readily organized, we may recall non–self-referent information easily as well (Klein & Kihlstrom, 1986). Finally, when we generate our own cues, we demonstrate much higher levels of recall than when someone else generates cues for us to use (Greenwald & Banaji, 1989).

Despite much supporting evidence, the LOP framework as a whole has its critics. For one thing, some researchers suggest that the particular levels may involve a cir-

### Table 5.2: Levels-of-Processing Framework

<table>
<thead>
<tr>
<th>Level of Processing</th>
<th>Basis for Processing</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical</td>
<td>Visually apparent features of the letters</td>
<td>Word: TABLE</td>
</tr>
<tr>
<td></td>
<td>Question: Is the word written in capital letters?</td>
<td></td>
</tr>
<tr>
<td>Phonological</td>
<td>Sound combinations associated with the letters (e.g., rhyming)</td>
<td>Word: CAT</td>
</tr>
<tr>
<td></td>
<td>Question: Does the word rhyme with “MAT”?</td>
<td></td>
</tr>
<tr>
<td>Semantic</td>
<td>Meaning of the word</td>
<td>Word: DAFFODIL</td>
</tr>
<tr>
<td></td>
<td>Question: Is the word a type of plant?</td>
<td></td>
</tr>
</tbody>
</table>
cular definition. On this view, the levels are defined as deeper because the information is retained better. But the information is viewed as being retained better because the levels are deeper. In addition, some researchers noted some paradoxes in retention. For example, under some circumstances, strategies that use rhymes have produced better retention than those using just semantic rehearsal. For example, focusing on superficial sounds and not underlying meanings can result in better retention than focusing on repetition of underlying meanings. Specifically, consider what happens when the context for retrieval involves attention to phonological (acoustic) properties of words (e.g., rhymes). Here, performance is enhanced when the context for encoding involves rehearsal based on phonological properties, rather than on semantic properties of words (Fisher & Craik, 1977, 1980). Nonetheless, consider what happened when semantic retrieval, based on semantic encoding, was compared with acoustic (rhyme) retrieval, based on rhyme encoding. Performance was greater for semantic retrieval than for acoustic retrieval (Fisher & Craik, 1977).

In light of these criticisms and some contrary findings, the LOP model has been revised. The sequence of the levels of encoding may not be as important as the match between the type of elaboration of the encoding and the type of task required for retrieval (Morris, Bransford, & Franks, 1977). Furthermore, there appear to be two kinds of strategies for elaborating the encoding. The first is within-item elaboration. It elaborates encoding of the particular item (e.g., a word or other fact) in terms of its characteristics, including the various levels of processing. The second kind of strategy is between-item elaboration. It elaborates encoding by relating each item’s features (again, at various levels) to the features of items already in memory. Thus, suppose you wanted to be sure to remember something in particular. You could elaborate it at various levels for each of the two strategies.

Elaboration strategies have practical applications: In studying, you may wish to match the way in which you encode the material to the way in which you will be expected to retrieve it in the future. Furthermore, the more elaborately and diversely you encode material, the more readily you are likely to recall it later in a variety of task settings. Just looking over material again and again in the same way is less likely to be productive for learning the material than is finding more than one way in which to learn it. If the context for retrieval will require you to have a deep understanding of the information, you should find ways to encode the material at deep levels of processing, such as by asking yourself meaningful questions about the material.

An Integrative Model: Working Memory

The working-memory model is probably the most widely used and accepted today. Psychologists who use it view short-term and long-term memory from a different perspective (e.g., Baddeley, 1990a, 1995; Cantor & Engle, 1993; Daneman & Carpenter, 1980; Daneman & Tardif, 1987; Engle, 1994; Engle, Cantor, & Carullo, 1992). Table 5.3 shows the contrasts between the Atkinson-Shiffrin model and an alternative perspective. Note the semantic distinctions, the differences in metaphorical representation, and the differences in emphasis for each view. The key feature of the alternative view
is the role of working memory. Working memory holds only the most recently activated, or conscious, portion of long-term memory, and it moves these activated elements into and out of brief, temporary memory storage (Dosher, 2003).

Alan Baddeley has suggested an integrative model of memory (Baddeley, 1990b, 1992, 1993, 1997; Baddeley & Hitch, 1974). It synthesizes the working-memory model with the LOP framework. Essentially, he views the LOP framework as an extension of, rather than as a replacement for, the working-memory model.

Baddeley originally suggested that working memory comprises four elements. The first is a visuospatial sketchpad, which briefly holds some visual images. The second is a phonological loop, which briefly holds inner speech for verbal comprehension and for acoustic rehearsal. We use the phonological loop for a number of everyday tasks, including sounding out new and difficult words and solving word problems. There are two critical components of this loop. One is phonological storage, which holds information in memory. The other is subvocal rehearsal, which is used to put the information into memory in the first place. The role of subvocal rehearsal can be seen in the following example. Consider trying to learn a list of words while repeating the number five. In this case subvocal rehearsal is inhibited and you would be unable

---

**TABLE 5.3** Traditional versus Nontraditional Views of Memory

Since Richard Atkinson and Richard Shiffrin first proposed their three-stores model of memory (which may be considered a traditional view of memory), various other models have been suggested.

<table>
<thead>
<tr>
<th>Terminology: definition of memory stores</th>
<th>Traditional Three-Stores View</th>
<th>Alternative View of Memory*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Terminology: definition of memory stores</td>
<td>Working memory is another name for short-term memory, which is distinct from long-term memory.</td>
<td>Working memory (active memory) is that part of long-term memory that comprises all the knowledge of facts and procedures that recently has been activated in memory, including the brief, fleeting short-term memory and its contents.</td>
</tr>
<tr>
<td>Metaphor for envisioning the relationships</td>
<td>Short-term memory may be envisioned as being distinct from long-term memory, perhaps either alongside it or hierarchically linked to it.</td>
<td>Short-term memory, working memory, and long-term memory may be envisioned as nested concentric spheres, in which working memory contains only the most recently activated portion of long-term memory and short-term memory contains only a very small, fleeting portion of working memory.</td>
</tr>
<tr>
<td>Metaphor for the movement of information</td>
<td>Information moves directly from long-term memory to short-term memory and then back—never in both locations at once.</td>
<td>Information remains within long-term memory; when activated, information moves into long-term memory's specialized working memory, which actively will move information into and out of the short-term memory store contained within it.</td>
</tr>
<tr>
<td>Emphasis</td>
<td>Distinction between long- and short-term memory.</td>
<td>Role of activation in moving information into working memory and the role of working memory in memory processes.</td>
</tr>
</tbody>
</table>

*Examples of researchers holding this view: Cantor & Engle, 1993; Engle, 1994; Engle, Cantor, & Carullo, 1992.
to rehearse the new words. When subvocal rehearsal is inhibited, the new information is not stored. This is called **articulatory suppression**. Articulatory suppression is more pronounced when the information is presented visually versus aurally.

The amount of information that can be manipulated within the phonological loop is limited. Thus, we can remember fewer long words compared with short words (Baddeley, 2000b). Without this loop, acoustic information decays after about 2 seconds. The third element is a **central executive**, which both coordinates attentional activities and governs responses. The central executive is critical to working memory because it is the gating mechanism that decides what information to process further and how to process it. It decides what resources to allocate to memory and related tasks, and how to allocate them. It is also involved in higher-order reasoning and comprehension and is central to human intelligence. The fourth element is a number of other “**subsidiary slave systems**” that perform other cognitive or perceptual tasks (Baddeley, 1989, p. 36). Recently, another component, the **episodic buffer**, has been added to working memory (Baddeley, 2000a, 2001). The episodic buffer is a limited-capacity system that is capable of binding information from the subsidiary systems and from long-term memory into a unitary episodic representation. This component integrates information from different parts of working memory—that is, visual spatial and phonological—so that they make sense to us. This incorporation allows us to solve problems and reevaluate previous experiences with more recent knowledge.

Neuropsychological methods, and especially brain imaging, can be very helpful in understanding the nature of memory (Buckner, 2000a, 2000b; Cabeza & Nyberg, 1997; Markowitsch, 2000; Nyberg & Cabeza, 2000; Rosenzweig, 2003; Rugg & Allan, 2000; Ungerleider, 1995). Support for a distinction between working memory and long-term memory comes from neuropsychological research. Neuropsychological studies have shown abundant evidence of a brief memory buffer. The buffer is used for remembering information temporarily. It is distinct from long-term memory, which is used for remembering information for long periods (Rudner & associates, 2007; Schacter, 1989a; Smith & Jonides, 1995; Squire, 1986; Squire & Knowlton, 2000). Furthermore, through some promising new research using positron emission tomography (PET) techniques, investigators have found evidence for distinct brain areas involved in the different aspects of working memory. The phonological loop, maintaining speech-related information, appears to involve bilateral activation of the frontal and parietal lobes (Cabeza & Nyberg, 1997). It is interesting that the visuospatial sketchpad appears to activate slightly different areas. Which ones it activates depends on the length of the retention interval. Shorter intervals activate areas of the occipital and right frontal lobes. Longer intervals activate areas of the parietal and left frontal lobes (Haxby & associates, 1995). The central executive functions appear to involve activation mostly in the frontal lobes (Roberts, Robbins, & Weiskrantz, 1996). Finally, the episodic buffer operations seem to involve the bilateral activation of the frontal lobes and portions of the temporal lobes, including the left hippocampus (Rudner & associates, 2007). Whereas the three-store view emphasizes the structural receptacles for stored information, the working-memory model underscores the functions of working memory in governing the processes of memory. These processes include encoding and integrating information. Examples are integrating acoustic and visual information through cross-modality, organizing information into meaningful chunks, and linking new information to existing forms of knowledge representation in long-term memory.
We can conceptualize the differing emphases with contrasting metaphors. For example, we can compare the three-store view to a warehouse in which information is passively stored. The sensory store serves as the loading dock. The short-term store comprises the area surrounding the loading dock. Here, information is stored temporarily until it is moved to or from the correct location in the warehouse. A metaphor for the working-memory model might be a multimedia production house. It continuously generates and manipulates images and sounds. It also coordinates the integration of sights and sounds into meaningful arrangements. Once images, sounds, and other information are stored, they still are available for reformatting and reintegration in novel ways, as new demands and new information become available. Different aspects of working memory are represented in the brain differently. Figure 5.4 shows some of these differences.

Working memory can be measured through a number of different tasks. The most commonly used are shown in Figure 5.5.

Task a is a retention delay task. It is the simplest task shown in the figure. An item is shown—in this case, a geometric shape. (The + at the beginning is merely a focus point to indicate that the series of items is beginning.) There is then a retention interval, which may be filled with other tasks, or unfilled; in which case time passes without any specifically designed intervening activity. The participant is then presented with a stimulus and must say whether it is old or new. In the figure, the stimulus being tested is new. So “new” would be the correct answer.

Task b is a temporally ordered working memory load task. A series of items is presented. After a while, the series of asterisks indicates that a test item will be presented. The test item is presented, and the participant must say whether the item is old or new. Because “4,” the number in the figure, has not been presented before, the correct answer is “new.”

Task c is a temporal order task. A series of items is presented. Then the asterisks indicate a test item will be given. The test item shows two previously presented items, 3 and 7. The participant must indicate which of the two numbers, 3 or 7, appeared more recently. The correct answer is 7 because 7 occurred after 3 in the list.

Task d is an n-back task. Stimuli are presented. At specified points, one is asked to repeat the stimulus that occurred n presentations back. For example, one might be asked to repeat the digit that occurred 1 back—or just before (as with the 6). Or one might be asked to repeat the digit that occurred 2 back (as with the 7).

Task e is a temporally ordered working memory load task. It can also be referred to simply as a digit-span task (when digits are used). One is presented with a series of stimuli. After they are presented, one repeats them back in the order they were presented. A variant of this task has the participant repeat them back in the order opposite to that in which they were presented—from the end to the beginning.

Finally, Task f is a temporally ordered working memory load task. One is given a series of simple arithmetic problems. For each problem, one indicates whether the sum or difference is correct. At the end, one repeats the results of the arithmetic problems in their correct order.

Each of the tasks described here and in Figure 5.5 allows for the examination of how much information we can manipulate in memory. Frequently, these tasks are paired with a second task (called, appropriately, a secondary task) so that researchers can learn more about the central executive. The central executive is responsible for allocating attentional and other resources to ongoing tasks. By having participants do more than one task at once, we can examine how mental resources are assigned (Bau-
FIGURE 5.5


(a) Retention delay task
- Item task: retention delay (filled or unfilled)
- Item test

(b) Temporally ordered working memory load
- Item task: old or new?

(c) Temporal order task
- Relational (order) task
- Test: which is most recent?

(d) n-back task
- Relational (order) task
- Task: find repeat n-back

(e) Temporally ordered working memory load
- Span task
- Item task: item test
- Task: reproduce in correct order

(f) Temporally ordered working memory load
- Running span task
- Task: reproduce final items in correct order

A task that often is paired with those listed in Figure 5.5 is a random-number generation task. In this task, the participant has to try to generate a random series of numbers while completing a working memory task (Rudkin, Pearson, & Logie, 2007).

The working-memory model is consistent with the notion that multiple systems may be involved in the storage and retrieval of information. Recall that when Wilder Penfield electrically stimulated the brains of his patients, the patients often asserted that they vividly recalled particular episodes and events. They did not, however, recall semantic facts that were unrelated to any particular event. These findings suggest that there may be at least two separate explicit memory systems. One would be for organizing and storing information with a distinctive time referent. It would address questions such as, “What did you eat for lunch yesterday?” or “Who was the first person you saw this morning?” The second system would be for information that has no particular time referent. It would address questions such as, “Who were the two psychologists who first proposed the three-stores model of memory?” and “What is a mnemonist?”

Based on such findings, Endel Tulving (1972) proposed a distinction between two kinds of explicit memory. Semantic memory stores general world knowledge. It is our memory for facts that are not unique to us and that are not recalled in any particular temporal context. Episodic memory stores personally experienced events or episodes. According to Tulving, we use episodic memory when we learn lists of words or when we need to recall something that occurred to us at a particular time or in a particular context. For example, suppose I needed to remember that I saw Harrison Hardimanowitz in the dentist’s office yesterday. I would be drawing on an episodic memory. But if I needed to remember the name of the person I now see in the waiting room (“Harrison Hardimanowitz”), I would be drawing on a semantic memory. There is no particular time tag associated with the name of that individual being Harrison. But there is a time tag associated with my having seen him at the dentist’s office yesterday.

Tulving (1983, 1989) and others (e.g., Shoben, 1984) provide support for the distinction between semantic and episodic memory. It is based on both cognitive research and neurological investigation. The neurological investigations have involved electrical-stimulation studies, studies of patients with memory disorders, and cerebral blood flow studies. For example, lesions in the frontal lobe appear to affect recollection regarding when a stimulus was presented. But they do not affect recall or recognition memory that a particular stimulus was presented (Schacter, 1989a).

It is not clear that semantic and episodic memories are two distinct systems. Nevertheless, they sometimes appear to function in different ways. Many cognitive psychologists question this distinction (e.g., Baddeley, 1984; Eysenck & Keane, 1990; Humphreys, Bain, & Pike, 1989; Johnson & Hasher, 1987; Ratcliff & McKoon, 1986; Richardson-Klavehn & Bjork, 1988). They point to blurry areas on the boundary between these two types of memory. They also note methodological problems with some of the supportive evidence. Perhaps episodic memory is merely a specialized form of semantic memory (Tulving, 1984, 1986). Some neurological evidence suggests that

**Multiple Memory Systems**

The working-memory model is consistent with the notion that multiple systems may be involved in the storage and retrieval of information. Recall that when Wilder Penfield electrically stimulated the brains of his patients, the patients often asserted that they vividly recalled particular episodes and events. They did not, however, recall semantic facts that were unrelated to any particular event. These findings suggest that there may be at least two separate explicit memory systems. One would be for organizing and storing information with a distinctive time referent. It would address questions such as, “What did you eat for lunch yesterday?” or “Who was the first person you saw this morning?” The second system would be for information that has no particular time referent. It would address questions such as, “Who were the two psychologists who first proposed the three-stores model of memory?” and “What is a mnemonist?”

Based on such findings, Endel Tulving (1972) proposed a distinction between two kinds of explicit memory. Semantic memory stores general world knowledge. It is our memory for facts that are not unique to us and that are not recalled in any particular temporal context. Episodic memory stores personally experienced events or episodes. According to Tulving, we use episodic memory when we learn lists of words or when we need to recall something that occurred to us at a particular time or in a particular context. For example, suppose I needed to remember that I saw Harrison Hardimanowitz in the dentist’s office yesterday. I would be drawing on an episodic memory. But if I needed to remember the name of the person I now see in the waiting room (“Harrison Hardimanowitz”), I would be drawing on a semantic memory. There is no particular time tag associated with the name of that individual being Harrison. But there is a time tag associated with my having seen him at the dentist’s office yesterday.

Tulving (1983, 1989) and others (e.g., Shoben, 1984) provide support for the distinction between semantic and episodic memory. It is based on both cognitive research and neurological investigation. The neurological investigations have involved electrical-stimulation studies, studies of patients with memory disorders, and cerebral blood flow studies. For example, lesions in the frontal lobe appear to affect recollection regarding when a stimulus was presented. But they do not affect recall or recognition memory that a particular stimulus was presented (Schacter, 1989a).

It is not clear that semantic and episodic memories are two distinct systems. Nevertheless, they sometimes appear to function in different ways. Many cognitive psychologists question this distinction (e.g., Baddeley, 1984; Eysenck & Keane, 1990; Humphreys, Bain, & Pike, 1989; Johnson & Hasher, 1987; Ratcliff & McKoon, 1986; Richardson-Klavehn & Bjork, 1988). They point to blurry areas on the boundary between these two types of memory. They also note methodological problems with some of the supportive evidence. Perhaps episodic memory is merely a specialized form of semantic memory (Tulving, 1984, 1986). Some neurological evidence suggests that
A memory is a mental experience that is taken to be a veridical (truthful) representation of an event from one’s past. Memories can be false in relatively minor ways (e.g., believing one last saw the car keys in the kitchen when they were in the living room) and in major ways that have profound implications for oneself and others (e.g., mistakenly believing one is the source or originator of an idea, or believing that one was sexually abused as a child when one was not). Such memory distortions reflect errors arising from imperfect source monitoring processes—the processes by which we make attributions about the origin of activated information in mental experience. Source monitoring errors include both confusions between internal and external sources of information and between various external sources (e.g., attributing something that was imagined to perception, an intention to an action, something one heard about to something one witnessed, something read in a tabloid to a television program, an incident that occurred in place A or time A to place B or time B). The integration of information across individual experiences from different sources is necessary for all higher-order, complex thought. But this very creativity makes us vulnerable to having false memories because we sometimes misattribute the sources of the information that comes to mind. Several types of evidence indicate that the prefrontal cortex (PFC) plays a key role in identifying the sources of mental experiences. Damage to the PFC produces deficits in source memory. Source memory deficits are more likely in children (whose frontal lobes are slow to develop) and in older adults (who are likely to show increased neuropathology in the PFC with age). PFC dysfunction may play a role in schizophrenia, which sometimes includes severe source monitoring deficits in the form of delusions.

My lab currently is using functional magnetic resonance imaging (fMRI) to help clarify the brain regions involved in source monitoring. In one type of study, participants saw a series of items of two types (pictures and words). Later they were given a memory test in which they were shown some words that corresponded to the items seen earlier (old items) intermixed with some that did not correspond to any of the items seen earlier (new items). We compared the brain activity when participants were asked to make source judgments (e.g., say “yes” to items previously seen as pictures) with brain activity when they were simply asked to decide whether a test item was familiar (say “yes” to any previously presented item). We found greater activity in the left PFC in the source identification compared with the old/new test condition (and sometimes greater activity in the right PFC as well). Furthermore, several other labs have reported related findings providing converging evidence that the left PFC is recruited in monitoring the origin of memories. Other studies suggest that the right PFC is engaged when judgments can be made on the basis of more global, less specific information such as familiarity or recency. It appears that processes subserved by both the right and left PFC contribute to evaluating the origin of mental experiences, possibly in different ways, and interactions between right and left hemispheres are likely important. Thus, one goal for future research is to more specifically relate component processes of memory to patterns of activity across various regions of the PFC and to specify how PFC regions interact with other brain regions in producing the subjective experiences we take to be memories.

**Suggested Readings**


these two types of memory are separate, however. Through neuropsychological methods, investigators found dissociations in brain areas for semantic versus episodic memory retrieval (Prince, Tsukiura, & Cabeza, 2007). Further research on patients with specific types of memory loss found the patients with a loss of semantic memory but no impairment of episodic memory (Temple & Richardson, 2004), again suggesting separate systems for episodic and semantic memory. Other researchers examining a different type of memory loss noted an impairment of episodic memory but intact semantic memory (Vargha-Khadem & associates, 1997). These findings all support the conclusion that there are separate episodic and semantic memory systems.

Other findings, however, suggest that the neural processes involved in these memories overlap (Rajah & McIntosh, 2005). Clearly, there is substantial evidence that there are differences between these two types of memory, both behavioral and neurological. Most researchers agree, however, that there is, at the very least, a great deal of interaction between these two types of memory. As a result, the question of whether these forms of memory are separate is still open.

A neuroscientific model attempts to account for differences in hemispheric activation for semantic versus episodic memories. According to this model, HERA (hemispheric encoding/retrieval asymmetry), there is greater activation in the left than in the right prefrontal hemisphere for tasks requiring retrieval from semantic memory (Nyberg, Cabeza, & Tulving, 1996; Tulving & associates, 1994). In contrast, there is more activation in the right than in the left prefrontal hemisphere for episodic-retrieval tasks. This model, then, proposes that semantic and episodic memories must be distinct because they draw on separate areas of the brain. For example, if one is asked to generate verbs that are associated with nouns (e.g., “drive” with “car”), this task requires semantic memory. It results in greater left-hemispheric activation (Nyberg, Cabeza, & Tulving, 1996). In contrast, if people are asked to freely recall a list of words, an episodic-memory task, they show more right-hemispheric activation.

A taxonomy of the memory system in terms of the dissociations described in the previous sections is shown in Figure 5.6 (Squire, 1986, 1993). It distinguishes de-

---

**FIGURE 5.6**

Based on extensive neuropsychological research, Larry Squire has posited that memory comprises two fundamental types: declarative (explicit) memory and various forms of nondeclarative (implicit) memory, each of which may be associated with discrete cerebral structures and processes.

Copyright 2009 Cengage Learning, Inc. All Rights Reserved. May not be copied, scanned, or duplicated, in whole or in part.
clarative (explicit) memory from various kinds of nondeclarative (implicit) memory. Nondeclarative memory comprises procedural memory, priming effects, simple classical conditioning, habituation, sensitization, and perceptual aftereffects. In yet another view, there are five memory systems in all: episodic, semantic, perceptual (i.e., recognizing things on the basis of their form and structure), procedural, and working (Schacter, 2000).

**A Connectionist Perspective**

The network model provides the structural basis for connectionist parallel distributed processing (PDP) model (Frean, 2003; Sun, 2003). According to the PDP model, the key to knowledge representation lies in the connections among various nodes, not in each individual node (Feldman & Shastri, 2003). Activation of one node may prompt activation of a connected node. This process of spreading activation may prompt the activation of additional nodes. The PDP model fits nicely with the notion of working memory as comprising the activated portion of long-term memory. In this model, activation spreads through nodes within the network. This spreading continues as long as the activation does not exceed the limits of working memory. A prime is a node that activates a connected node. A priming effect is the resulting activation of the node. The priming effect has been supported by considerable evidence. Examples are the aforementioned studies of priming as an aspect of implicit memory. In addition, some evidence supports the notion that priming is due to spreading activation (McClelland & Rumelhart, 1985, 1988). But not everyone agrees about the mechanism for the priming effect (see McKoon & Ratcliff, 1992b).

Connectionist models also have some intuitive appeal in their ability to integrate several contemporary notions about memory: Working memory comprises the activated portion of long-term memory and operates through at least some amount of parallel processing. Spreading activation involves the simultaneous (parallel) activation (priming) of multiple links among nodes within the network. Many cognitive psychologists who hold this integrated view suggest that part of the reason we humans are as efficient as we are in processing information is that we can handle many operations at once. Thus, the contemporary cognitive-psychological conceptions of working memory, network models of memory, spreading activation, priming, and parallel processes mutually enhance and support one another.

Some of the research supporting this connectionist model of memory has come directly from experimental studies of people performing cognitive tasks in laboratory settings. Connectionist models effectively explain priming effects, skill learning (procedural memory), and several other phenomena of memory. Thus far, however, connectionist models have failed to provide clear predictions and explanations of recall and recognition memory that occurs following a single episode or a single exposure to semantic information.

In addition to using laboratory experiments on human participants, cognitive psychologists have used computer models to simulate various aspects of information processing. The three-stores model is based on serial (sequential) processing of information. Serial processing can be simulated on individual computers that handle only
one operation at a time. In contrast, the parallel-processing model of working memory, which involves simultaneous processing of multiple operations, cannot be simulated on a single computer. Parallel processing requires neural networks. In these networks, multiple computers are linked and operate in tandem. Alternatively, a single special computer may operate with parallel networks. Many cognitive psychologists now prefer a parallel-processing model to describe many phenomena of memory. The parallel-processing model was actually inspired by observing how the human brain seems to process information. Here, multiple processes go on at the same time. In addition to inspiring theoretical models of memory function, neuropsychological research has offered specific insights into memory processes. It also has provided evidence regarding various hypotheses of how human memory works.

Not all cognitive researchers accept the connectionist model. Some believe that human thought is more systematic than connectionist models will allow (Fodor & Pylyshyn, 1988; Matthews, 2003). They believe that complex behavior displays a degree of orderliness and purposefulness that connectionist models cannot incorporate. Connectionist modelers dispute this claim. The issue will be resolved as cognitive psychologists explore the extent to which connectionist models can reproduce and even explain complex behavior.

Memory in the Real World

How is memory used in everyday situations, and what is memory for? Some researchers believe we should study memory in more real-world settings, in addition to laboratory settings (Cohen, 1989; Neisser, 1978, 1982). The basic idea is that memory research should have ecological validity and apply to natural memory phenomena in natural settings. The techniques used therefore examine naturalistic settings using self-reports and questionnaires. Although this approach has been criticized for its lack of control and generalizability (Banaji & Crowder, 1989), it has generated some interesting new conceptualizations into the nature of memory research in general.

For example, one set of researchers has called for a change in the metaphor used in conceptualizing memory, rather than a change in the research setting. The traditional storehouse metaphor of memory, in which memory is conceived of as a repository of information and events, inevitably leads to questions of quantity. The question thus becomes: How many items can be remembered from or used in a particular occasion (Koriat & Goldsmith, 1996a, 1996b)? The laboratory setting is most congenial to this approach, allowing for control over the variables of quantity. In contrast, the everyday or real-world approach calls for more of a correspondence metaphor. Here, memory is conceived of as a vehicle for interaction with the real world. Thus, the questions shift toward accuracy in representing past events. How closely does memory correspond to particular events? Here, memory would be viewed as a structure fulfilling a particular purpose in our interactions with the world.

We may see this new trend broadening as more researchers become increasingly interested in the functional properties of memory. Already some promising new insights into the question of what memory is for offer some concrete proposals into the structure of memory. For example, one view calls for a memory system centered
around bodily interactions with the environment (Glenberg, 1997). Thus, correspondence with the real world is achieved via representations that reflect the structural relationship between the body and the external world, rather than the encoding of abstract symbolic representations.

Whether this approach will take the lead in memory research or be overcome by the impetus of the laboratory-storehouse metaphor remains to be seen. Whatever the case may be, new metaphors and controversies are essential for the survival of the field. Without a constant flow of new ideas or rethinking of old ideas, science would stagnate and die. Another approach that already is beginning to dominate much of memory research is the neuropsychological study of memory. It developed in part from the study of people with exceptional memory.

**Exceptional Memory and Neuropsychology**

Up to this point, the discussion of memory has focused on tasks and structures involving normally functioning memory. However, there are rare cases of people with exceptional memory (either enhanced or deficient) that provide some interesting insights into the nature of memory in general. The study of exceptional memory leads directly to neuropsychological investigations of the physiological mechanisms underlying memory.

**Outstanding Memory: Mnemonists**

Imagine what your life would be like if you had outstanding memory abilities. Suppose, for example, you were able to remember every word printed in this book. In this case, you would be considered an **mnemonist**, someone who demonstrates extraordinarily keen memory ability, usually based on using special techniques for memory enhancement. Perhaps the most famous of mnemonists was a man called “S.”

Russian psychologist Alexander Luria (1968) reported that one day S. appeared in his laboratory and asked to have his memory tested. Luria tested him. He discovered that the man’s memory appeared to have virtually no limits. S. could reproduce extremely long strings of words, regardless of how much time had passed since the words had been presented to him. Luria studied S. over 30 years. He found that even when S.’s retention was measured 15 or 16 years after a session in which S. had learned words, S. still could reproduce the words. S. eventually became a professional entertainer. He dazzled audiences with his ability to recall whatever was asked of him.

What was S.’s trick? How did he remember so much? Apparently, he relied heavily on the mnemonic of visual imagery. He converted material that he needed to remember into visual images. For example, he reported that when asked to remember the word *green*, he would visualize a green flowerpot. For the word *red*, he visualized a man in a red shirt coming toward him. Even numbers called up images. For example, 1 was a proud, well-built man. The number 3 was a gloomy person. The number 6 was a man with a swollen foot, and so on.

For S., much of his use of visual imagery in memory recall was not intentional. Rather, it was the result of a rare psychological phenomenon. This phenomenon,
termed synesthesia, is the experience of sensations in a sensory modality different from
the sense that has been physically stimulated. For example, S. automatically would
convert a sound into a visual impression. He even reported experiencing a word's
taste and weight. Each word to be remembered evoked a whole range of sensations.
They automatically would come to S. when he needed to recall that word.

Other mnemonicists have used different strategies. V. P., a Russian immigrant,
could memorize long strings of material such as rows and columns of numbers (Hunt
& Love, 1972). Whereas S. relied primarily on visual imagery, V. P. apparently relied
more on verbal translations. He reported memorizing numbers by transforming them
into dates. Then he would think about what he had done on that day.

Another mnemonicist, S. F., remembered long strings of numbers by segmenting
them into groups of three or four digits each. He then encoded them into running
times for different races (Ericsson, Chase, & Faloon, 1980). An experienced long-
distance runner, S. F. was familiar with the times that would be plausible for different
races. S. F. did not enter the laboratory as a mnemonicist. Rather, he had been selected
to represent the average college student in terms of intelligence and memory ability.

S. F.'s original memory for a string of numbers was about seven digits, average for a
college student. After 200 practice sessions distributed over a period of 2 years, however,
S. F. had increased his memory for digits more than 10-fold. He could recall up to about
80 digits. His memory was impaired severely, however, when the experimenters pur-
posefully gave him sequences of digits that could not be translated into running times. The
work with S. F. suggests that a person with a fairly typical level of memory ability can,
at least in principle, be converted into one with quite an extraordinary memory. At
least, this is possible in some domains, following a great deal of concerted practice.

Many of us yearn to have memory abilities like those of S. or V. P. In this way, we
may believe we could ace our exams virtually effortlessly. However, we should con-
sider that S. was not particularly happy with his life, and part of the reason was his
exceptional memory. He reported that his synesthesia, which was largely involuntary,
interfered with his ability to listen to people. Voices gave rise to blurs of sensations.
They in turn interfered with his ability to follow a conversation. Moreover, S.'s heavy
reliance on imagery created difficulty for him when he tried to understand abstract
concepts. For example, he found it hard to understand concepts such as infinity or
nothing. These concepts do not lend themselves well to visual images. He also some-
times was overwhelmed when he read. Earlier memories also sometimes intruded on
later ones. Of course, we cannot say how many of S.'s problems in life were caused by
his exceptional memory. But clearly S. believed that his exceptional memory had a
downside as well as an upside. It was often as likely to be a hindrance as a help.

These exceptional mnemonicists offer some insight into processes of memory. Each
of the three described here did more or less the same thing—consciously or almost
automatically. Each translated arbitrary, abstract, meaningless information into more
meaningful or more sensorially concrete information. Whether the translated infor-
mation was racing times, dates and events, or visual images, the key was their mean-
ing for the mnemonicist.

Like the mnemonicists, we more easily encode information into our long-term
memory that is similar to the information already stored there. Because we have in-
formation in long-term memory that pertains to our interests, it is easier to learn new
information that is in line with these interests and that we can relate to the old in-
formation (De Beni & associates, 2007). Thus, you may be able to remember the lyrics of your favorite songs from years ago but not be able to recall the definitions of new terms that you have just learned. You can improve your memory for new information if you can relate the new information to old information already stored in long-term memory.

If you are unable to retrieve a memory that you need, does it mean that you have forgotten it? Not necessarily. Cognitive psychologists have studied a phenomenon called hypermnesia, which is a process of producing retrieval of memories that would seem to have been forgotten (Erdelyi & Goldberg, 1979; Holmes, 1991; Turtle & Yuille, 1994). Hypermnesia is sometimes loosely referred to as “unforgetting,” although the terminology cannot be correct because, strictly speaking, the memories that are retrieved were never unavailable (i.e., forgotten), but rather, inaccessible (i.e., hard to retrieve). Hypermnesia is usually achieved by trying many and diverse retrieval cues to unearth a memory. Psychodynamic therapy, for example, is sometimes used to try to achieve hypermnesia. This therapy also points out the risk of trying to achieve hypermnesia. The individual may create a new memory, believing it is an old one, rather than retrieving a genuine old memory.

We usually take for granted the ability to remember, much like the air we breathe. However, just as we become more aware of the importance of air when we do not have enough to breathe, we are less likely to take memory for granted when we observe people with serious memory deficiencies.

**Deficient Memory**

Several different syndromes are associated with memory loss. The most well known is amnesia.

If the patient uses hypermnesia to dredge up what has seemed to be a forgotten memory, we often cannot be certain that the memory is genuine, rather than one newly created by suggestion.
**Amnesia**

Amnesia is severe loss of explicit memory (Mayes & Hunkin, 2003). One type is retrograde amnesia, in which individuals lose their purposeful memory for events prior to whatever trauma induces memory loss (Squire, 1999). Mild forms of retrograde amnesia can occur fairly commonly when someone sustains a concussion. Usually, events immediately prior to the concussive episode are not well remembered.

W. Ritchie Russell and P. W. Nathan (1946) reported a more severe case of retrograde amnesia. A 22-year-old greenkeeper was thrown from his motorcycle in August 1933. A week after the accident, the young man was able to converse sensibly. He seemed to have recovered. However, it quickly became apparent that he had suffered a severe loss of memory for events that had occurred prior to the trauma. On questioning, he gave the date as February 1922. He believed himself to be a schoolboy. He had no recollection of the intervening years. Over the next several weeks, his memory for past events gradually returned. The return started with the least recent and proceeded toward more recent events. By 10 weeks after the accident, he had recovered his memory for most of the events of the previous years. He finally was able to recall everything that had happened up to a few minutes prior to the accident. In retrograde amnesia, the memories that return typically do so starting from the more distant past. They then progressively return up to the time of the trauma. Often events right before the trauma are never recalled.

Another kind of amnesia is one that almost all of us experience. It is infantile amnesia, the inability to recall events that happened when we were very young (Spear, 1979). Generally, we can remember little or nothing that has happened to us before the age of about 5 years. It is extremely rare for someone to recall many memories before age 3 years. The few reports of childhood memories that are recorded usually involve memories of significant events. Examples are the birth of a sibling or the death of a parent (Fivush & Hamond, 1991). For example, some adults have recalled their own hospitalization or the birth of a sibling as far back as age 2 years. The death of a parent or a family move may be recalled from as far back as age 3 years (Usher & Neisser, 1993). The probability that an early event will be recalled is affected by intelligence, education, and language ability (Pillemer & White, 1989). Furthermore, asking adults to recall events from their preschool years results in many more remembered events than when adults are asked to report their earliest memory (Nelson & Fivush, 2004).

The accuracy of reported childhood memories has come into question recently, however. In fact, many psychologists suggest that the accuracy of children’s recollections of events may be questionable even shortly after these events occurred (e.g., Ceci & Bruck, 1993). The memories are particularly suspect if the children are exposed to covert or overt suggestions regarding the remembered material. (The unreliability of our memories for events is discussed more fully in the next chapter.)

One of the most famous cases of amnesia is the case of H. M. (Scoville & Milner, 1957). H. M. underwent brain surgery to save him from continual disruptions due to uncontrollable epilepsy. The operation took place on September 1, 1953. It was largely experimental. The results were highly unpredictable. At the time of the operation, H. M. was 29 years old. He was above average in intelligence. After the operation, his recovery was uneventful with one exception. He suffered severe anterograde amnesia, the inability to remember events that occur after a traumatic event.
However, he had good (although not perfect) recollection of events that had occurred before his operation. H. M.’s memory loss severely affected his life. H.M. has been extensively studied through behavioral and neurological methods. On one occasion, he remarked, “Every day is alone in itself, whatever enjoyment I’ve had, and whatever sorrow I’ve had” (Milner, Corkin, & Teuber, 1968, p. 217). Many years after the surgery, H.M. still reported that the year was 1953. He also could not recall the name of any new person he met after the operation, regardless of the number of times they interacted. Apparently, H. M. lost his ability purposefully to recollect any new memories of the time following his operation. As a result, he lives suspended in an eternal present.

The examination of H.M.’s memory is ongoing, with recent work examining changes in H.M.’s memory and brain as he ages. These recent studies have noted additional memory and cognitive declines. In particular, H. M. exhibited new problems with comprehension and generation of new sentences (MacKay, 2006; MacKay & associates, 2006; Salat & associates, 2006; Skotko & associates, 2004).

**Amnesia and the Explicit-Implicit Memory Distinction**

Research psychologists study amnesia patients in part to gain insight into memory functioning in general. One of the general insights gained by studying amnesia victims highlights the distinction between explicit and implicit memories. Explicit memory is typically impaired in amnesia. Implicit memory, such as priming effects on word-completion tasks and procedural memory for skill-based tasks, is typically not impaired. Apparently two kinds of abilities need to be distinguished. The first is the ability to reflect consciously on prior experience, which is required for tasks involving explicit memory of declarative knowledge. The second is the ability to demonstrate remembered learning in an apparently automatic way, without conscious recollection of the learning (Baddeley, 1989). Amnesia victims perform extremely poorly on most explicit memory tasks, but they may show normal or almost-normal performance on tasks involving implicit memory, such as cued-recall tasks (Warrington & Weiskrantz, 1970) and word-completion tasks (Baddeley, 1989). Consider what happens following word-completion tasks. When amnesics were asked whether they previously had seen the word they just completed, they were unlikely to remember the specific experience of having seen the word (Graf, Mandler, & Haden, 1982; Tulving, Schacter, & Stark, 1982). Furthermore, these amnesics do not explicitly recognize words they have seen at better than chance levels. Although the distinction between implicit memory and explicit memory has been readily observed in amnesics, both amnesics and normal participants show the presence of implicit memory.

Likewise, amnesia victims also show paradoxical performance in another regard. Consider two kinds of tasks. As previously described, procedural-knowledge tasks involve “knowing how.” They involve skills such as how to ride a bicycle, whereas declarative-knowledge tasks involve “knowing that.” They tap factual information, such as the terms in a psychology textbook. On the one hand, amnesia victims may perform extremely poorly on the traditional memory tasks requiring recall or recognition memory of declarative knowledge. On the other hand, they may demonstrate improvement in performance resulting from learning—remembered practice—when engaged in tasks that require procedural knowledge. Such tasks would include solving puzzles, learning to read mirror writing, or mastering motor skills (Baddeley, 1989).
Consider an example of this spared procedural knowledge. Patients with amnesia, when asked to drive in a normal situation, were able to operate and control the car as a normal driver would (Anderson & associates, 2007). However, the investigators also exposed the patients to a simulation in which a complex accident sequence was experienced. In this situation, the patients with amnesia showed significant impairment. They could not recall the proper response to this situation. This finding is in line with the fact that in patients with amnesia, implicit, procedural knowledge is spared while explicit knowledge is impaired. Most drivers do not have extensive experience with complex accident-avoidance scenarios and therefore would have to rely more on their declarative memory to make decisions about how to respond.

**Amnesia and Neuropsychology**

Studies of amnesia victims have revealed much about the way in which memory depends on the effective functioning of particular structures of the brain. By looking for matches between particular lesions in the brain and particular deficits of function, researchers come to understand how normal memory functions. Thus, when studying different kinds of cognitive processes in the brain, neuropsychologists frequently look for dissociations of function. In dissociations, normal individuals show the presence of a particular function (e.g., explicit memory). But people with specific lesions in the brain show the absence of that particular function. This absence occurs despite the presence of normal functions in other areas (e.g., implicit memory).

By observing people with disturbed memory function, we know that memory is volatile. A blow to the head, a disturbance in consciousness, or any number of other injuries to or diseases of the brain may affect it. We cannot determine, however, the specific cause-effect relationship between a given structural lesion and a particular memory deficit. The fact that a particular structure or region is associated with an interruption of function does not mean that the region is solely responsible for controlling that function. Indeed, functions can be shared by multiple structures or regions. A broad physiological analogy may help to explain the difficulty of determining localization based on an observed deficit. The normal functioning of a portion of the brain—the reticular activating system (RAS)—is essential to life. But life depends on more than a functioning brain. If you doubt the importance of other structures, ask a patient with heart or lung disease. Thus, although the RAS is essential to life, a person’s death may be the result of malfunction in other structures of the body. Tracing a dysfunction within the brain to a particular structure or region poses a similar problem.

For the observation of simple dissociations, many alternative hypotheses may explain a link between a particular lesion and a particular deficit of function. Much more compelling support for hypotheses about cognitive functions comes from observing double dissociations. In double dissociations, people with different kinds of neuropathological conditions show opposite patterns of deficits. For some functions and some areas of the brain, neuropsychologists have managed to observe the presence of a double dissociation. For example, some evidence for distinguishing brief memory from long-term memory comes from just such a double dissociation (Schacter, 1989b). People with lesions in the left parietal lobe of the brain show profound inability to retain information in short-term memory, but they show no impairment of long-term memory. They continue to encode, store, and retrieve information in long-term memory, apparently with little difficulty (Shallice & Warrington, 1970; War-
rington & Shallice, 1972). In contrast, persons with lesions in the medial (middle) temporal regions of the brain show relatively normal short-term memory of verbal materials, such as letters and words, but they show serious inability to retain new verbal materials in long-term memory (Milner, Corkin, & Teuber, 1968; Shallice, 1979; Warrington, 1982).

Double dissociations offer strong support for the notion that particular structures of the brain play particular vital roles in memory (Squire, 1987). Disturbances or lesions in these areas cause severe deficits in memory formation. But we cannot say that memory—or even part of memory—resides in these structures. Nonetheless, studies of brain-injured patients are informative and at least suggestive of how memory works. At present, cognitive neuropsychologists have found that double dissociations support several distinctions. These distinctions are those between brief memory and long-term memory and between declarative (explicit) and nondeclarative (implicit) memory. There also are some preliminary indications of other distinctions.

**Alzheimer’s Disease**

Although amnesia is the syndrome most associated with memory loss, it is often less devastating than a disease that includes memory loss as one of many symptoms. Alzheimer’s disease is a disease of older adults that causes dementia as well as progressive memory loss (Kensinger & Corkin, 2003). Dementia is a loss of intellectual function that is severe enough to impair one’s everyday life. The memory loss in Alzheimer’s disease can be seen in comparative brain scans of individuals with and without Alzheimer’s disease. Note in Figure 5.7 that as the disease advances, there is diminishing cognitive activity in the areas of the brain associated with memory function.

The disease was first identified by Alois Alzheimer in 1907. It is typically recognized on the basis of loss of intellectual function in daily life. Formally, a definitive diagnosis is possible only after death. The brains of people with the disease show plaques and tangles that are not found in normal brains. Plaques are dense deposits found outside the nerve cells of the brain. They are spherical structures with a dense core of amyloid β-protein (Kensinger & Corkin, 2003). Tangles are pairs of filaments that become twisted around each other. They are found in the cell body and dendrites of neurons and often are shaped like a flame (Kensinger & Corkin, 2003). Alzheimer’s disease is diagnosed when memory is impaired and there is at least one other area of dysfunction in the domains of language, motor, attention, executive function, personality, or object recognition. The symptoms are of gradual onset, and the progression is continuous and irreversible.

Although the progression of disease is irreversible, it can be slowed somewhat. The main drug currently being used for this purpose is Aricept (donepezil). Research evidence is mixed (Fischman, 2004). It suggests that, at best, Aricept may slightly slow progression of the disease, but that it cannot reverse it. A more recent drug, memantine (sold as Namenda or Ebixa), can supplement Aricept and slow progression of the disease somewhat more. The two drugs have different mechanisms. Aricept slows destruction of the neurotransmitter acetylcholine in the brain. Memantine inhibits a chemical that overexcites brain cells and leads to cell damage and death (Fischman, 2004).

The incidence of Alzheimer’s increases exponentially with age (Kensinger & Corkin, 2003). The incidence at ages 70 to 75 is about 1% per year. But between ages
By age 70, 30% to 50% of adults have Alzheimer’s symptoms, and after 80 years, the percentage is in excess of 50%.

A special kind of Alzheimer’s disease is familial, known as early-onset Alzheimer’s disease. It has been linked to a genetic mutation. People with the genetic mutation always develop the disease. It results in the disease exhibiting itself early, often before even 50 years of age and sometimes as early as the 20s (Kensinger & Corkin, 2003). Late-onset Alzheimer’s, in contrast, appears to be complexly determined and related to a variety of possible genetic and environmental influences, none of which have been conclusively identified.

The earliest signs of Alzheimer’s disease typically include impairment of episodic memory. People have trouble remembering things that were learned in a temporal or spatial context. As the disease progresses, semantic memory also begins to go. Whereas people without the disease tend to remember emotionally charged information better than they remember non–emotionally charged information, people with
the disease show no difference in the two kinds of memory (Kensinger & associates, 2002). Most forms of nondeclarative memory are spared in Alzheimer’s disease until near the very end of its course. The end is inevitably death unless the individual dies first of other causes.

**Role of the Hippocampus and Other Structures**

Where in the brain are memories stored, and what structures and areas of the brain are involved in memory processes, such as encoding and retrieval? Many early attempts at localization of memory were unfruitful. For example, after literally hundreds of experiments, renowned neuropsychologist Karl Lashley reluctantly stated that he could find no specific locations in the brain for specific memories. In the decades since Lashley’s admission, psychologists have been able to locate many cerebral structures involved in memory. For example, they know of the importance of the hippocampus and other nearby structures. However, the physiological structure may not be such that we will find Lashley’s elusive localizations of specific ideas, thoughts, or events. Even Penfield’s findings regarding links between electrical stimulation and episodic memory of events have been subject to question.

Some studies show encouraging, although preliminary, findings regarding the structures that seem to be involved in various aspects of memory. First, specific sensory properties of a given experience appear to be organized across various areas of the cerebral cortex (Squire, 1986). For example, the visual, spatial, and olfactory (odor) features of an experience may be stored discretely in each of the areas of the cortex responsible for processing of each type of sensation. Thus, the cerebral cortex appears to play an important role in memory in terms of the long-term storage of information (Zola & Squire, 2000; Zola-Morgan & Squire, 1990).

In addition, the hippocampus and some related nearby cerebral structures appear to be important for explicit memory of experiences and other declarative information. The hippocampus also seems to play a key role in the encoding of declarative information (Squire & Zola-Morgan, 1991; Thompson, 2000; Thompson & Krupa, 1994; Zola-Morgan & Squire, 1990). Its main function appears to be in the integration and consolidation of separate sensory information (Moscovitch, 2003). Most important, it is involved in the transfer of newly synthesized information into long-term structures supporting declarative knowledge. Perhaps such transfer provides a means of cross-referencing information stored in different parts of the brain (Reber, Knowlton, & Squire, 1996; Squire, 1986; Squire, Cohen, & Nadel, 1984). Additionally, the hippocampus seems to play a crucial role in complex learning (McCormick & Thompson, 1984). The amygdala also appears to play an important role in memory consolidation, especially where emotional experience is involved (Cahill & associates, 1995; Cahill & McGaugh, 1996; Ledoux, 1996; McGaugh, 1999; McGaugh, Cahill, & Roozenaala, 1996; Packard, Cahill, & McGaugh, 1994). Finally, the hippocampus also has a significant role in the recollection of information (Gilboa & associates, 2006).

In evolutionary terms, the aforementioned cerebral structures (chiefly the cortex and the hippocampus) are relatively recent acquisitions. Declarative memory also may be considered a relatively recent phenomenon. At the same time, other memory structures may be responsible for nondeclarative forms of memory. For example, the basal ganglia seem to be the primary structures controlling procedural knowledge (Mishkin & Petri, 1984). But they are not involved in controlling the priming effect.
(Heindel, Butters, & Salmon, 1988), which may be influenced by various other kinds of memory (Schacter, 1989b). Furthermore, the cerebellum also seems to play a key role in memory for classically conditioned responses and contributes to many cognitive tasks in general (Cabeza & Nyberg, 1997; Thompson, 1987). Thus, various forms of nondeclarative memory seem to rely on differing cerebral structures.

In addition to these preliminary insights regarding the macro-level structures of memory, we are beginning to understand the micro-level structure of memory. For example, we know that repeated stimulation of particular neural pathways tends to strengthen the likelihood of firing. In particular, at a particular synapse, there appear to be physiological changes in the dendrites of the receiving neuron. These changes make the neuron more likely to reach the threshold for firing again.

We also know that some neurotransmitters disrupt memory storage. Others enhance memory storage. Both serotonin and acetylcholine seem to enhance neural transmission associated with memory. Norepinephrine also may do so. High concentrations of acetylcholine have been found in the hippocampus of normal people (Squire, 1987), but low concentrations are found in people with Alzheimer's disease. In fact, Alzheimer's patients show severe loss of the brain tissue that secretes acetylcholine.

Memory tests may be given to assess whether an individual has Alzheimer's disease. However, definitive diagnosis is possible only through analysis of brain tissue, which, as mentioned earlier, shows plaques and tangles in cases of disease. In one test, individuals see a sheet of paper containing four words (Buschke & associates, 1999). Each word belongs to a different category. The examiner says the category name for one of the words. The individual must point to the appropriate word. For example, if the category is animal, the individual might point to a picture of a cow. A few minutes after the words have been presented, individuals make an attempt to recall all the words they saw. If they cannot recall a word, they are given the category to which the word belongs. Some individuals cannot remember the words, even when prompted with the categories. Alzheimer's patients score much worse on this test than do other individuals.

Researchers have been better able to track down the cause of another form of memory dysfunction, but they have not devised a way to eliminate this preventable deficit. Alcohol consumption has been shown to disrupt the activity of serotonin. It thereby impairs the formation of memories (Weingartner & associates, 1983). In fact, severe or prolonged abuse of alcohol can lead to Korsakoff's syndrome, a devastating form of anterograde amnesia. This syndrome is often accompanied by at least some retrograde amnesia (Clark & associates, 2007; Parkin, 1991; Shimamura & Squire, 1986). Korsakoff's syndrome has been linked to damage in the diencephalon (the region comprising the thalamus and the hypothalamus) of the brain (Jernigan & associates, 1991; Langlais, Mandel, & Mair, 1992). It also has been linked to dysfunction or damage in other areas (Jacobson & Lishman, 1990), such as in the frontal (Parsons & Nixon, 1993; Squire, 1982) and the temporal (Blansjaar & associates, 1992) lobes of the cortex.

Other physiological factors also affect memory function. Some of the naturally occurring hormones stimulate increased availability of glucose in the brain, which enhances memory function. These hormones are often associated with highly arousing events. Examples of such events are traumas, achievements, first-time experiences (e.g., first passionate kiss), crises, or other peak moments (e.g., reaching a major decision). They may play a role in remembering these events.

The amygdala is often associated with emotional events, so a natural question to ask is whether, in memory tasks, there is involvement of the amygdala in memory for
emotionally charged events. In one study, participants saw two video presentations presented on separate days (Cahill & associates, 1996). Each presentation involved 12 clippings, half of which had been judged as involving relatively emotional content and the other half as involving relatively unemotional content. As participants watched the video clippings, brain activity was assessed by means of PET (see Chapter 2). After a gap of 3 weeks, the participants returned to the lab and were asked to recall the clips. For the relatively emotional clips, amount of activation in the amygdala was associated with recall; for the relatively unemotional clips, there was no association. This pattern of results suggests that when memories are emotionally charged, level of amygdala activation is associated with recall. In other words, the more emotionally charged the emotional memory, the greater the probability the memory will later be retrieved. There also may be a sex difference with regard to recall of emotional memories. There is some evidence that women recall emotionally charged pictures better than do men (Canli & associates, 2002).

Some of the most fascinating work has focused more on the strategies used in regard to memory. Memory strategies and memory processes are the subject of the following chapter.

**Key Themes**

This chapter illustrates some of the key themes noted in Chapter 1.

First, it shows how basic and applied research can interact. An example is research on Alzheimer's disease. At the present time, the disease is not curable, but it is treatable. It can be treated with drugs and with guidance provided in a structured living environment. Basic research into the biological structures (e.g., tangles and plaques) and cognitive functions (e.g., impaired memory) associated with Alzheimer's may one day help us better understand and treat the disease.

Second, the chapter shows the interaction of biology with behavior. The hippocampus has become one of the most carefully studied parts of the brain. Current functional magnetic resonance imaging (fMRI) research is showing how the hippocampus and other parts of the brain, such as the amygdala (in the case of emotionally based memories) and the cerebellum (in the case of procedural memories) function to enable us to remember what we need to know.

Third, the chapter shows how structure and function are both important to understanding human memory. The Atkinson-Shiffrin model proposed control processes that operate on three structures: a very short-term store, a short-term store, and a long-term store. The more recent working-memory model proposes how executive function controls and activates portions of long-term memory to provide the information needed to solve tasks at hand.

After you use an ATM with a friend, ask him or her to fill in the blank: A_M. Your friend will most likely say “ATM.” If you were to do this without visiting an ATM, most people will likely say “ARM.” The first response is an example of implicit memory.

Ask some friends or family members to help you with a memory experiment. Give half of them the instruction to count the number of letters in the words you are about
to recite. Give the other half the instruction to think of three words related to the words you are about to recite. Recite the following words about 5 seconds apart: beauty, ocean, competitor, bad, decent, happy, brave, beverage, artistic, dejected. About 5 or 10 minutes later, ask your friends to write down as many of the 10 words as they can remember. In general, those who were asked to think of three related words to the words you read will remember more than those who were asked to count the number of letters in the words. This is a demonstration of levels of processing. Those friends who thought of three related words processed the words more deeply than those who merely counted up the number of letters in the words. Words that are processed more deeply are remembered better.

Summary

1. What are some of the tasks used for studying memory, and what do various tasks indicate about the structure of memory? Among the many tasks used by cognitive psychologists, some of the main ones have been tasks assessing explicit recall of information (e.g., free recall, serial recall, and cued recall) and tasks assessing explicit recognition of information. By comparing memory performance on these explicit tasks with performance on implicit tasks (e.g., word-completion tasks), cognitive psychologists have found evidence of differing memory systems or processes governing each type of task (e.g., as shown in studies of amnesics).

2. What has been the prevailing traditional model of the structure of memory? Memory is the means by which we draw on our knowledge of the past to use this knowledge in the present. According to one model, memory is conceived as involving three stores. A sensory store is capable of holding relatively limited amounts of information for very brief periods. A short-term store is capable of holding small amounts of information for somewhat longer periods. And a long-term store is capable of storing large amounts of information virtually indefinitely. Within the sensory store, the iconic store refers to visual sensory memory.

3. What are some of the main alternative models of the structure of memory? An alternative model uses the concept of working memory, usually defined as being part of long-term memory and also comprising short-term memory. From this perspective, working memory holds only the most recently activated portion of long-term memory. It moves these activated elements into and out of short-term memory. A second model is the levels-of-processing framework, which hypothesizes distinctions in memory ability based on the degree to which items are elaborated during encoding. A third model is the multiple memory systems model, which posits not only a distinction between procedural memory and declarative (semantic) memory but also a distinction between semantic and episodic memory. In addition, psychologists have proposed other models for the structure of memory. They include a parallel distributed processing (PDP; connectionist) model. The PDP model incorporates the notions of working memory, semantic memory networks, spreading activation, priming, and parallel processing of information. Finally, many psychologists call for a complete change in the conceptualization of memory, focusing on memory functioning in the real world. This call leads to a shift in memory metaphors from the traditional storehouse to the more modern correspondence metaphor.

4. What have psychologists learned about the structure of memory by studying exceptional memory and the physiology of the brain? Among other findings, studies of mnemonists have shown the value of imagery in memory for concrete information. They also have demon-
Although specific memory traces have not yet been identified, many of the specific structures involved in memory function have been located. To date, the subcortical structures involved in memory appear to include the hippocampus, the thalamus, the hypothalamus, and even the basal ganglia and the cerebellum. The cortex also governs much of the long-term storage of declarative knowledge.

The neurotransmitters serotonin and acetylcholine appear to be vital to memory function. Other physiological chemicals, structures, and processes also play important roles, although further investigation is required to identify these roles.

Thinking about Thinking: Factual, Analytical, Creative, and Practical Questions

1. Describe two characteristics each of sensory memory, short-term memory, and long-term memory.

2. What are double dissociations, and why are they valuable to understanding the relationship between cognitive function and the brain?

3. Compare and contrast the three-stores model of memory with one of the alternative models of memory.

4. Critique one of the experiments described in this chapter. What problem do you see regarding the interpretation given? How could subsequent research be designed to enhance the interpretation of the findings?

5. How would you design an experiment to study some aspect of implicit memory?

6. Imagine what it would be like to recover from one of the forms of amnesia. Describe your impressions of and reactions to your newly recovered memory abilities.

7. How would your life be different if you could greatly enhance your own mnemonic skills in some way?

Key Terms

Alzheimer’s disease  iconic store  priming effect
amnesia  implicit memory  recall
anterograde amnesia  infantile amnesia  recognition
central executive  levels-of-processing framework  retrograde amnesia
episodic buffer  long-term store  semantic memory
episodic memory  memory  sensory store
explicit memory  mnemonicist  short-term store
hypermnesia  phonological loop  visuospatial sketchpad
hypothetical constructs  prime  working memory
Explore CogLab by going to [http://coglab.wadsworth.com](http://coglab.wadsworth.com).
To learn more, examine the following experiments:

- Memory Span
- Partial Report
- Absolute Identification
- Operation Span
- Implicit Learning
- Modality Effect
- Position Error
- Irrelevant Speech
- Phonological Similarity
- Levels of Processing

**Annotated Suggested Reading**

Chapter 6

Memory Processes

Exploring Cognitive Psychology

Encoding and Transfer of Information
- Forms of Encoding
- Transfer of Information from Short-Term Memory to Long-Term Memory

Retrieval
- Retrieval from Short-Term Memory
- Retrieval from Long-Term Memory

Processes of Forgetting and Memory Distortion
- Interference versus Decay Theory

The Constructive Nature of Memory
- Autobiographical Memory
- Memory Distortions
- Context Effects on Encoding and Retrieval

Memory Development
- Metacognitive Skills and Memory Development

Key Themes
Summary
Thinking about Thinking: Factual, Analytical, Creative, and Practical Questions
Key Terms
Annotated Suggested Readings
The procedure is actually quite simple. First you arrange items into different groups. Of course one pile may be sufficient depending on how much there is to do. If you have to go somewhere else due to lack of facilities that is the next step; otherwise, you are pretty well set. It is important not to overdo things. That is, it is better to do too few things at once than too many. In the short run this may not seem important but complications can easily arise. A mistake can be expensive as well. At first, the whole procedure will seem complicated. Soon, however, it will become just another facet of life. It is difficult to foresee any end to the necessity for this task in the immediate future, but then, one can never tell. After the procedure is completed one arranges the materials into different groups again. Then they can be put into their appropriate places. Eventually they will be used once more and the whole cycle will then have to be repeated. However, that is part of life.

John Bransford and Marcia Johnson (1972, p. 722) asked their participants to read the preceding passage and to recall the steps involved. To get an idea of how easy it was for their participants to do so, try to recall those steps now yourself. Bransford and Johnson’s participants (and probably you, too) had a great deal of difficulty understanding this passage and recalling the steps involved. What makes this task so difficult? What are the mental processes involved in this task?

As mentioned in the previous chapter, cognitive psychologists generally refer to the main processes of memory as comprising three common operations: encoding, storage, and retrieval. Each one represents a stage in memory processing. Encoding refers to how you transform a physical, sensory input into a kind of representation that can be placed into memory. Storage refers to how you retain encoded information in memory. Retrieval refers to how you gain access to information stored in memory. Our emphasis in discussing these processes will be on recall of verbal and pictorial material. Remember, however, that we have memories of other kinds of stimuli as well, such as odors (Herz & Engen, 1996).

Encoding, storage, and retrieval often are viewed as sequential stages. You first take in information. Then you hold it for a while. Later you pull it out. However, the processes interact with each other and are interdependent. For example, you may have found the text in the chapter-opening paragraph difficult to encode, thereby also making it hard to store and to retrieve the information. However, a verbal label can facilitate encoding and hence storage and retrieval. Most people do much better with the passage if given its title, “Washing Clothes.” Try now to recall the steps described.
in the passage. The verbal label helps us to encode, and therefore to remember, a passage that otherwise seems incomprehensible.

**Encoding and Transfer of Information**

**Forms of Encoding**

**Short-Term Storage**

When you encode information for temporary storage and use, what kind of code do you use? Participants were visually presented with several series of six letters at the rate of 0.75 seconds per letter (Conrad, 1964). The letters used in the various lists were B, C, F, M, N, P, S, T, V, and X. Immediately after the letters were presented, participants had to write down each list of six letters in the order given. What kinds of errors did participants make? Despite the fact that letters were presented visually, errors tended to be based on acoustic confusability. In other words, instead of recalling the letters they were supposed to recall, participants substituted letters that sounded like the correct letters. Thus, they were likely to confuse F for S, B for V, P for B, and so on. Another group of participants simply listened to single letters in a setting that had noise in the background. They then immediately reported each letter as they heard it. Participants showed the same pattern of confusability in the listening task as in the visual memory task (Conrad, 1964). Thus, we seem to encode visually presented letters by how they sound, not by how they look.

The Conrad experiment shows the importance in short-term memory of an acoustic code rather than a visual code. But the results do not rule out the possibility that there are other codes. One such code would be a semantic code—one based on word meaning. One researcher argued that short-term memory relies primarily on an acoustic rather than a semantic code (Baddeley, 1966). He compared recall performance for lists of acoustically confusable words—such as map, cab, mad, man, and cap—with that for lists of acoustically distinct words—such as cow, pit, day, rig, and bun. He found that performance was much worse for the visual presentation of acoustically similar words.

He also compared performance for lists of semantically similar words—such as big, long, large, wide, and broad—with performance for lists of semantically dissimilar words—such as old, foul, late, hot, and strong. There was little difference in recall between the two lists. Suppose performance for the semantically similar words had been much worse. It would have indicated that participants were confused by the semantic similarities and hence were processing the words semantically. However, performance for the semantically similar words was only slightly worse than that for the semantically dissimilar words.

Subsequent work investigating how information is encoded in short-term memory has shown clear evidence of at least some semantic encoding in short-term memory (Shulman, 1970; Wickens, Dalezman, & Eggemeier, 1976). Thus, encoding in short-term memory appears to be primarily acoustic, but there may be some secondary semantic encoding as well. In addition, we sometimes temporarily encode information visually as well (Posner, 1969; Posner & associates, 1969; Posner &
Keele, 1967). But visual encoding appears to be even more fleeting (about 1.5 seconds). It also is more vulnerable to decay than acoustic encoding. Thus, initial encoding is primarily acoustic in nature, but other forms of encoding may be used under some circumstances.

**Long-Term Storage**

As mentioned, information stored temporarily in working memory is encoded primarily in acoustic form. Hence, when we make errors in retrieving words from short-term memory, the errors tend to reflect confusions in sound. How is information encoded into a form that can be transferred into storage and available for subsequent retrieval?

Most information stored in long-term memory seems to be primarily semantically encoded. In other words, it is encoded by the meanings of words. Consider some relevant evidence.

Participants learned a list of 41 different words (Grossman & Eagle, 1970). Five minutes after learning took place, participants were given a recognition test. Included in the recognition test were distracters. These are items that appear to be legitimate choices but that are not correct alternatives. That is, they were not presented previously. Nine of the distracters were semantically related to words on the list. Nine were not. The data of interest were false alarms to the distracters. These are responses in which the participants indicated that they had seen the distracters, although they had not. Participants falsely recognized an average of 1.83 of the synonyms but only an average of 1.05 of the unrelated words. This result indicated a greater likelihood of semantic confusion.

Another way to show semantic encoding is to use sets of semantically related test words, rather than distracters. Participants learn a list of 60 words that included 15 animals, 15 professions, 15 vegetables, and 15 names of people (Bousfield, 1953). The words were presented in random order. Thus, members of the various categories were intermixed thoroughly. After participants heard the words, they were asked to use free recall to reproduce the list in any order they wished. The investigator then analyzed the order of output of the recalled words. Did participants recall successive words from the same category more frequently than would be expected by chance? Indeed, successive recalls from the same category did occur much more often than would be expected by chance occurrence. Participants were remembering words by clustering them into categories.

Levels of processing, discussed in Chapter 5, also influences encoding in long-term memory. When learning lists of words, participants move more information into long-term memory when using a semantic encoding strategy than when using a non-semantic strategy. Interestingly, in people with autism, this advantage is not seen. This finding suggests that, in persons with autism, information may not be encoded semantically, or at least, not to the same extent as in people who do not have autism (Toichi & Kamio, 2002).

Encoding of information in long-term memory is not exclusively semantic. There also is evidence for visual encoding. Participants received 16 drawings of objects, including four items of clothing, four animals, four vehicles, and four items of furniture (Frost, 1972). The investigator manipulated not only the semantic category but also the visual category. The drawings differed in visual orientation. Four were angled to the left, four angled to the right, four horizontal, and four ver-
tical. Items were presented in random order. Participants were asked to recall them freely. The order of participants’ responses showed effects of both semantic and visual categories. These results suggested that participants were encoding visual as well as semantic information.

In addition to semantic and visual information, acoustic information can be encoded in long-term memory (Nelson & Rothbart, 1972). Thus, there is considerable flexibility in the way we store information that we retain for long periods. Those who seek to know the single correct way we encode information are seeking an answer to the wrong question. There is no one correct way. A more useful question involves asking, “In what ways do we encode information in long-term memory?” From a more psychological perspective, however, the most useful question to ask is, “When do we encode in which ways?” In other words, under what circumstances do we use one form of encoding, and under what circumstances do we use another? These questions are the focus of present and future research.

**Transfer of Information from Short-Term Memory to Long-Term Memory**

Given the problems of decay and interference, described later in this chapter, how do we move information from short-term memory to long-term memory? The means of moving information depend on whether the information involves declarative or non-declarative memory. Some forms of nondeclarative memory are highly volatile and decay quickly. Examples are priming and habituation. Other nondeclarative forms are maintained more readily, particularly as a result of repeated practice (of procedures) or repeated conditioning (of responses). Examples are procedural memory, such as tying one’s shoes, and simple classical conditioning, such as phobias.

Entrance into long-term declarative memory may occur through a variety of processes. One method of accomplishing this goal is by deliberately attending to information to comprehend it. Another is by making connections or associations between the new information and what we already know and understand. We make connections by integrating the new data into our existing schemas of stored information. **Consolidation** is this process of integrating new information into stored information. In humans, the process of consolidating declarative information into memory can continue for many years after the initial experience (Squire, 1986). Stress generally impairs the memory functioning. However, stress also can help enhance the consolidation of memory through the release of hormones (Roozendaal, 2002, 2003). The disruption of consolidation has been studied effectively in amnesics. Studies have particularly examined people who have suffered brief forms of amnesia as a consequence of electroconvulsive therapy (ECT; Squire, 1986). For these amnesics, the source of the trauma is clear. Confounding variables can be minimized. A patient history before the trauma can be obtained, and follow-up testing and supervision after the trauma are more likely to be available. A range of studies suggests that during the process of consolidation, our memory is susceptible to disruption and distortion.

To preserve or enhance the integrity of memories during consolidation, we may use various metamemory strategies (Koriat & Goldsmith, 1996a, 1996b; Metcalfe, 2000; Nelson & Narens, 1994; Schwartz & Metcalfe, 1994). **Metamemory** strategies involve reflecting on our own memory processes with a view to improving our mem-
ory. Such strategies are especially important when we are transferring new information to long-term memory by rehearsing it. Metamemory strategies are just one component of **metacognition**, our ability to think about and control our own processes of thought and ways of enhancing our thinking.

**Rehearsal**

One technique people use for keeping information active is **rehearsal**, the repeated recitation of an item. The effects of such rehearsal are termed **practice effects**. Rehearsal may be **overt**, in which case it is usually aloud and obvious to anyone watching. Or it may be **covert**, in which case it is silent and hidden. Just repeating words over and over again to oneself is not enough to achieve effective rehearsal (Tulving, 1962). One needs also to think about the words and, possibly, their inter-relationships. Whether rehearsal is overt or covert, what is the best way to organize your time for rehearsing new information?

More than a century ago, Hermann Ebbinghaus (1885, cited in Schacter, 1989a) noticed that the **distribution of study (memory rehearsal) sessions over time affects the consolidation of information in long-term memory**. Much more recently, researchers have offered support for Ebbinghaus’s observation as a result of their studies of people’s long-term recall of Spanish vocabulary words the subjects had learned 8 years earlier (Bahrick & Phelps, 1987). They observed that people’s memory for information depends on how they acquire it. Their memories tend to be good when they use **distributed practice**, learning in which various sessions are spaced over time. Their memories for information are not as good when the information is acquired through **massed practice**, learning in which sessions are crammed together in a very short space of time. The greater the distribution of learning trials over time, the more the participants remembered over long periods. This effect is termed the **spacing effect**.

Research has linked the spacing effect to the process by which memories are consolidated in long-term memory (Glenberg, 1977, 1979; Leicht & Overton, 1987). That is, the spacing effect may occur because at each learning session, the context for encoding may vary. The individuals may use alternative strategies and cues for encoding. They thereby enrich and elaborate their schemas for the information. The principle of the spacing effect is important to remember in studying. You will recall information longer, on average, if you distribute your learning of subject matter and you vary the context for encoding. Do not try to cram it all into a short period. Imagine studying for an exam in several short sessions over a 2-week period. You will remember much of the material. However, if you try to study all the material in just one night, you will remember very little and the memory for this material will decay relatively quickly.

Why would distributing learning trials over days make a difference? One possibility is that information is learned in variable contexts. These diverse contexts help strengthen and begin to consolidate it. Another possible answer comes from studies of the influences of sleep on memory. Of particular importance is the amount of rapid eye movement (REM) sleep, a particular stage of sleep characterized by dreaming and increased brainwave activity (Karni & associates, 1994). Specifically, disruptions in REM sleep patterns the night after learning reduced the amount of improvement on a visual discrimination task that occurred relative to normal sleep. Furthermore, this lack of improvement was not observed for disrupted stage-three or stage-four sleep.
patterns (Karni & associates, 1994). Other research also shows better learning with increases in the proportion of REM-stage sleep after exposure to learning situations (Ellenbogen, Payne, & Stickgold, 2006; Smith, 1996). The positive influence of sleep on memory consolidation is seen across age groups (Hornung & associates, 2007). People who suffer from insomnia, a disorder that deprives the sufferer of much-needed sleep, have trouble with memory consolidation (Backhaus & associates, 2006). These findings highlight the importance of biological factors in the consolidation of memory. Thus, a good night’s sleep, which includes plenty of REM-stage sleep, aids in memory consolidation.

Is there something special occurring in the brain that could explain why REM sleep is so important for memory consolidation? Neuropsychological research on animal learning may offer a tentative answer to this question. Recall that the hippocampus has been found to be an important structure for memory. In recording studies of rat hippocampal cells, researchers have found that cells of the hippocampus that were activated during initial learning are reactivated during subsequent periods of sleep. It is as if they are replaying the initial learning episode to achieve consolidation into long-term storage (Scaggs & McNaughton, 1996; Wilson & McNaughton, 1994). This effect has also been observed in humans. After learning routes within a virtual town, participants slept. Increased hippocampal activity was seen during sleep after the person had learned the spatial information. In the people with the most hippocampal activation, there was also an improvement in performance when they needed to recall the routes (Peigneux & associates, 2004). During this increased activity, the hippocampus also shows extremely low levels of the neurotransmitter acetylcholine. When patients were given acetylcholine during sleep, they showed impaired memory consolidation, but only for declarative information. Procedural memory consolidation was not affected by acetylcholine levels (Gais & Born, 2004).

In a recent review, investigators have proposed that the hippocampus acts as a rapid learning system (McClelland, McNaughton, & O’Reilly, 1995). It temporarily maintains new experiences until they can be appropriately assimilated into the more gradual neocortical representation system of the brain. Such a complementary system is necessary to allow memory to represent more accurately the structure of the environment. McClelland and his colleagues have used connectionist models of learning to show that integrating new experiences too rapidly leads to disruptions in long-term memory systems. Thus, the benefits of distributed practice seem to occur because we have a relatively rapid learning system in the hippocampus. It becomes activated during sleep. Repeated exposure on subsequent days and repeated reactivation during subsequent periods of sleep help learning. These rapidly learned memories become integrated into our more permanent long-term memory system.

A topic related to consolidation is reconsolidation. The process of consolidation makes memories less likely to undergo either interference or decay. However, after a memory is called back into consciousness, it may return to a more unstable state. In this state, the memory that was consolidated may again fall victim to interference or decay. To prevent this loss, a process of reconsolidation takes place. Reconsolidation has the same effect that consolidation does but is completed on previously encoded information. Reconsolidation does not necessarily occur with each memory we recall but does seem to occur with relatively newly consolidated material (Walker & associates, 2003).
The spacing of practice sessions affects memory consolidation. However, the
distribution of learning trials within any given session does not seem to affect mem-
ory. According to the total-time hypothesis, the amount of learning depends on the
amount of time spent mindfully rehearsing the material. This relation occurs more or
less without regard to how that time is divided into trials in any one session. The
total-time hypothesis does not always hold, however. Moreover, the total-time hy-
pothesis of rehearsal has at least two apparent constraints (Cooper & Pantle, 1967).
First, the full amount of time allotted for rehearsal actually must be used for that
purpose. Second, to achieve beneficial effects, the rehearsal should include various
kinds of elaboration or mnemonic devices that can enhance recall.

To move information into long-term memory, an individual must engage in
elaborative rehearsal. In elaborative rehearsal, the individual somehow elaborates
the items to be remembered. Such rehearsal makes the items either more meaning-
fully integrated into what the person already knows or more meaningfully con-
nected to one another and therefore more memorable. Consider, in contrast, main-
tenance rehearsal. In maintenance rehearsal, the individual simply repetitiously
rehearses the items to be repeated. Such rehearsal temporarily maintains informa-
tion in short-term memory without transferring the information to long-term
memory. Without any kind of elaboration, the information cannot be organized and
transferred.

**Organization of Information**

Stored memories are organized. One way to show this organization is through the
measurement of subjective organization in free recall. This refers to our individually
determined ways of organizing our memories. To measure subjective organization,
researchers may give participants a multi-trial free-recall task. Participants have mul-
tiple trials during which to learn to recall in any order they choose a list of unrelated
words. Recall that if sets of test words can be divided into categories (e.g., names of
fruits or of furniture), participants spontaneously will cluster their recall output by
these categories. They do so even if the order of presentation is random (Bousfield,
1953). Similarly, participants will tend to show consistent patterns of word order in
their recall protocols, even if there are no apparent relations among words in the list
(Tulving, 1962). In other words, participants create their own consistent organiza-
tion. They then group their recall by the subjective units they create. Although most
adults spontaneously tend to cluster items into categories, categorical clustering also
may be used intentionally as an aid to memorization.

---

You can use these memory strategies to help you study for exams:

1. Study throughout the course rather than cram the night before an exam. This
distributes the learning sessions, allowing for consolidation into more permanent
memory systems.
2. Link new information to what you already know by rehearsing new information
in meaningful ways. Organize new information to relate it to other coursework
or areas of your life.
3. Use the various mnemonic devices shown in Table 6.1.

---

PRACTICAL APPLICATIONS OF COGNITIVE PSYCHOLOGY
Mnemonic devices are specific techniques to help you memorize lists of words (Best, 2003). Essentially, such devices add meaning to otherwise meaningless or arbitrary lists of items. As Table 6.1 shows, a variety of methods—categorical clustering, acronyms, acrostics, interactive imagery among items, pegwords, and the method of loci—can help you to memorize lists of words and vocabulary items. Although the techniques described in Table 6.1 are not the only available ones, they are among the most frequently used.

- In **categorical clustering**, one organizes a list of items into a set of categories. For example, one might organize one’s shopping list by the types of foods to be bought (e.g., fruits, vegetables, meats).
- In **interactive images**, one imagines (as vividly as possible) the objects represented by words one has to remember interacting with each other in some active way. For example, suppose you have to remember interacting with socks, apples, and a pair of scissors. You might imagine cutting with a pair of scissors a sock that has an apple stuffed in it.

### Table 6.1

Mnemonic Devices: Assorted Techniques

Of the many mnemonic devices available, the ones described here rely either on organization of information into meaningful chunks, such as categorical clustering, acronyms, and acrostics, or on visual images, such as interactive images, a pegword system, and the method of loci.

<table>
<thead>
<tr>
<th>Technique</th>
<th>Explanation/Description</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Categorical clustering</td>
<td>Organize a list of items into a set of categories</td>
<td>If you needed to remember to buy apples, milk, bagels, grapes, yogurt, rolls, Swiss cheese, grapefruit, and lettuce, you would be better able to do so if you tried to memorize the items by categories: fruits—apples, grapes, grapefruit; dairy products—milk, yogurt, Swiss cheese; breads—bagels, rolls; vegetables—lettuce.</td>
</tr>
<tr>
<td>Interactive images</td>
<td>Create interactive images that link the isolated words in a list</td>
<td>Suppose, for example, that you need to remember a list of unrelated words: aardvark, table, pencil, book, radio, Kansas, rain, electricity, stone, mirror. You might better remember these words by generating interactive images. For example, you might imagine an aardvark sitting on a table holding a pencil in its claws and writing in a book, with rain pouring over Kansas (as pictured on a map) that lands on a radio that is sitting on a stone, which generates electricity reflected in a mirror.</td>
</tr>
<tr>
<td>Pegword system</td>
<td>Associate each new word with a word on a previously memorized list, and form an interactive image between the two words</td>
<td>One such list is from a nursery rhyme: One is a bun. Two is a shoe. Three is a tree. Four is a door. Five is a hive. Six is a stick. Seven is heaven. Eight is a gate. Nine is a dime. Ten is a hen. To recall the list of words you used for the interactive images system, you might visualize an aardvark eating a delicious bun. You might imagine a shoe atop a tall table. You might visualize one large branch of a tree that ends with a sharp pencil point. Then you would go on forming interactive images for each of the words in the list. When you need to remember the words, you first recall the numbered images and then recall the words as you visualize them in the interactive images.</td>
</tr>
</tbody>
</table>
In the **pegword system**, one associates each word with a word on a previously memorized list and forms an interactive image between the two words. For example, you might memorize a list such as “One is a bun,” “Two is a shoe,” “Three is a tree,” and so on. To remember that you need to buy socks, apples, and a pair of scissors, you might imagine an apple between two buns, a sock stuffed inside a shoe, and a pair of scissors cutting a tree.

In the **method of loci**, one visualizes walking around an area with distinctive landmarks that one knows well. One then links the various landmarks to specific items to be remembered. For example, suppose you have three landmarks on your route to school—a strange-looking house, a tree, and a baseball diamond. You might imagine a big sock on top of the house in place of the chimney, the pair of scissors cutting the tree, and apples replacing bases on the baseball diamond.

In using **acronyms**, one devises a word or expression in which each of its letters stands for a certain other word or concept. An example is UK for the United Kingdom.

### TABLE 6.1

<table>
<thead>
<tr>
<th>Technique</th>
<th>Explanation/Description</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Method of loci</td>
<td>Visualize walking around an area with distinctive landmarks that you know well, and then link the various landmarks to specific items to be remembered</td>
<td>When you need to memorize a list of words, mentally walk past each of the distinctive landmarks, depositing each word to be memorized at one of the landmarks. Visualize an interactive image between the new word and the landmark. For example, if you wished to remember the list of items mentioned previously, you might envision an <em>aardvark</em> nibbling at the roots of a familiar tree, a <em>table</em> sitting on the sidewalk in front of an empty lot, a <em>pencil</em>-shaped statue in the center of a fountain, and so on. When you wished to remember the list, you would take your mental walk and pick up the words you had linked to each of the landmarks along the walk.</td>
</tr>
<tr>
<td>Acronym</td>
<td>Devise a word or expression in which each of its letters stands for a certain other word or concept (e.g., USA, IQ, and laser)</td>
<td>Suppose that you want to remember the names of the mnemonic devices described in this chapter. The acronym “IAM PACK” might prompt you to remember Interactive images, Acronyms, Method of loci, Pegwords, Acrostics, Categories, and Keywords. Of course, this technique is more useful if the first letters of the words to be memorized actually can be formed into a word phrase, or something close to one, even if the word or phrase is nonsensical, as in this example.</td>
</tr>
<tr>
<td>Acrostic</td>
<td>Form a sentence rather than a single word to help you remember the new words</td>
<td>Music students trying to memorize the names of the notes found on lines of the treble clef (the higher notes; specifically E, G, B, D, and F above middle C) learn that “Every Good Boy Does Fine.”</td>
</tr>
<tr>
<td>Keyword system</td>
<td>Form an interactive image that links the sound and meaning of a foreign word with the sound and meaning of a familiar word</td>
<td>Suppose that you needed to learn that the French word for <em>butter</em> is <em>beurre</em>. First, you would note that <em>beurre</em> sounds something like “bear.” Next, you would associate the keyword <em>bear</em> with <em>butter</em> in an image or sentence. For instance, you might visualize a bear eating a stick of butter. Later, <em>bear</em> would provide a retrieval cue for <em>beurre</em>.</td>
</tr>
</tbody>
</table>
• In using acrostics, one forms a sentence rather than a single word to help one remember new words. For example, one might remember that “every good boy does fine” to recall the names of notes found on the lines of the treble clef in music.

• In using the keyword system, one forms an interactive image that links the sound and meaning of a foreign word with the sound and meaning of a familiar word. To remember the word *libro*, for example, which means “book” in Spanish, one might associate *libro* with *liberty*. Then think of the Statue of Liberty holding up a large book instead of a torch.

What is the comparative effectiveness of various mnemonic strategies, including verbal elaborative rehearsal, mental imagery for isolated items, interactive images (linking a sequence of items), the method of loci, and the pegword system (Table 6.2)? The relative effectiveness of the methods for encoding is influenced by the kind of task (free recall versus serial recall) required at the time of retrieval (Roediger, 1980a). Thus, when choosing a method for encoding information for subsequent recall, one should consider the purpose for recalling the information. The individual should choose not only strategies that allow for effectively encoding the information (moving it into long-term memory). He or she also should choose strategies that offer appropriate cues for facilitating subsequent retrieval when needed. For example, prior to taking an exam in cognitive psychology, using a strategy for retrieving an alphabetical list of prominent cognitive psychologists would probably be relatively ineffective. Using a strategy for linking particular theorists with the key ideas of their theories is likely to be more effective.

The use of mnemonic devices and other techniques for aiding memory involves metamemory. Most adults spontaneously use categorical clustering. So its inclusion in this list of mnemonic devices is actually just a reminder to use this common memory strategy. In fact, each of us often uses various kinds of *reminders*—external memory aids—to enhance the likelihood that we will remember important information. For example, by now you have surely learned the benefits of various external memory aids. These include taking notes during lectures, writing shopping lists for items to purchase, setting timers and alarms, and even asking other people to help you remember things. In addition, we can design our environment to help us remember important information through the use of *forcing functions* (Norman, 1988). These are physical constraints that prevent us from acting without at least considering the key information to be remembered. For example, to ensure that you remember to take your notebook to class, you might lean the notebook against the door through which you must pass to go to class.

Most of the time, we try to improve our retrospective memory—our memory for the past. At times we also try to improve our prospective memory—memory for things we need to do or remember in the future. For example, we may need to remember to call someone, to buy cereal at the supermarket, or to finish a homework assignment due the next day. We use a number of strategies to improve prospective memory. Examples are keeping a to-do list, asking someone to remind us to do something, or tying a string around our finger to remind us that we need to do something. Research suggests that having to do something regularly on a certain day does not necessarily improve
prospective memory for doing that thing. However, being monetarily reinforced for doing the thing does tend to improve prospective memory (Meacham, 1982; Meacham & Singer, 1977).

Prospective memory, like retrospective memory, is subject to declines as we age. Over the years, we retain more of our prospective memory than of our retrospective memory. This retention is likely the result of the use of the external cues and strategies that can be used to bolster prospective memory. In the laboratory, older adults show a decline in prospective memory; however, outside the laboratory they show better performance than young adults. This difference may be due to greater reliance on strategies to aid in remembering as we age (Henry & associates, 2004).
Once we have stored information, how do we retrieve it when we want to do so? If we have problems retrieving information, how do we know whether we even stored the information in the first place?

**Retrieval from Short-Term Memory**

Once information is encoded and stored in short-term memory, how do people retrieve that information?

### INVESTIGATING COGNITIVE PSYCHOLOGY

Memorize the following list of numbers: 6, 3, 8, 2, 7. Now, was 8 on the list? How do people make decisions such as this one?

In one study, participants received a short list including from one to six digits (Sternberg, 1966). They were expected to be able to hold it in short-term memory. After a brief pause, a test digit was flashed on a screen. Participants had to say whether this digit appeared in the set that they had been asked to memorize. Thus, if the list comprised the digits 4, 1, 9, 3, and the digit 9 flashed on the screen, the correct response would be “yes.” If, instead, the test digit was 7, the correct response would be “no.” The digits that were presented are termed the *positive set*. Those that were not presented are termed the *negative set*. Results are shown in Figure 6.1.

Are items retrieved all at once (parallel processing) or sequentially (serial processing)? If retrieved serially, the question then arises, “Are all items retrieved, regardless of the task (exhaustive retrieval), or does retrieval stop as soon as an item seems to accomplish the task (self-terminating retrieval)?”

### Parallel versus Serial Processing

As mentioned previously, parallel processing refers to the simultaneous handling of multiple operations. As applied to short-term memory, the items stored in short-term memory would be retrieved all at once, not one at a time. The prediction in Figure 6.1 a shows what would happen if parallel processing were the case in the memory scanning task. Response times should be the same, regardless of the size of the positive set. This is because all comparisons would be done at once.

Serial processing refers to operations being done one after another. In other words, on the digit-recall task, the digits would be retrieved in succession, rather than all at once (as in the parallel model). According to the serial model, it should take longer to retrieve four digits than to retrieve two digits (as shown in Figure 6.1 b).

### Exhaustive versus Self-Terminating Processing

Suppose information processing were serial. Then there would be two ways in which to gain access to the stimuli: exhaustive or self-terminating processing. *Exhaustive serial processing* implies that the participant always would check the test digit against all digits in the positive set, even if a match were found partway through the list.
Exhaustive processing would predict the pattern of data shown in Figure 6.1 c. Note that positive responses all would take the same amount of time, regardless of the serial position of a positive test probe. In other words, in an exhaustive search, you would take the same amount of time to find any digit. Where in the list it was located would not matter.

Self-terminating serial processing implies that the participant would check the test digit against only those digits needed to make a response. Consider Figure 6.1 d. It shows that response time now would increase linearly as a function of where a test digit was located in the positive set. The later the serial position, the longer is the response time.

**The Winner—a Serial Exhaustive Model—with Some Qualifications**

The actual pattern of data was crystal clear. The data looked like those in Figures 6.1 b and c. Response times increased linearly with set size, but they were the same, regardless of serial position. Later, this pattern of data was replicated (Sternberg, 1969).
Moreover, the mean response times for positive and negative responses were essentially the same. This fact further supported the serial exhaustive model. Comparisons took roughly 38 milliseconds (0.038 seconds) apiece (Sternberg, 1966, 1969).

Although many investigators considered the question of parallel versus serial processing to have been answered decisively, in fact, a parallel model could account for the data (Corcoran, 1971). Imagine a horse race that involves parallel processing. The race is not over until the last horse passes the finish line. Now suppose we add more horses to the race. The length of the race (from the start until the last of the horses crosses the finishing line) is likely to increase. For example, if horses are selected randomly, the slowest horse in an eight-horse race is likely to be slower than the slowest horse in a four-horse race. That is, with more horses, a wider range of speeds is more likely. So the entire race will take longer because the race is not complete until the slowest horse crosses the finish line. Similarly, when applying a parallel model to a retrieval task involving more items, a wider range of retrieval speeds for the various items is also more likely. The entire retrieval process is not complete until the last item has been retrieved. Mathematically, it is impossible to distinguish parallel from serial models unequivocally (Townsend, 1971). There always exists some parallel model that will mimic any serial model in its predictions and vice versa. The two models may not be equally plausible, but they still exist. Moreover, it appears that what processes individuals use depends in part on the stimuli that are processed (e.g., Naus, 1974; Naus, Glucksberg, & Ornstein, 1972).

Some cognitive psychologists have suggested that we should seek not only to understand the how of memory processes but also the why of memory processes (e.g., Bruce, 1991). That is, what functions does memory serve for individual persons and for humans as a species? To understand the functions of memory, we must study memory for relatively complex information. We also need to understand the relationships between the information presented and other information available to the individual, both within the informational context and as a result of prior experience.

**Retrieval from Long-Term Memory**

It is difficult to separate storage from retrieval phenomena. Participants in one study were tested on their memory for lists of categorized words (Tulving & Pearlstone, 1966). Participants would hear words within a category together in the list. They even would be given the name of the category before the items within it were presented. For example, the participants might hear the category “article of clothing” followed by the words, “shirt, socks, pants, belt.” Participants then were tested for their recall.

The recall test was done in one of two ways. In the free-recall condition, participants merely recalled as many words as they could in any order they chose. In a cued-recall condition, however, participants were tested category by category. They were given each category label as a cue. They then were asked to recall as many words as they could from that category. The critical result was that cued recall was far better, on average, than free recall. Had the researchers tested only free recall, they might have concluded that participants had not stored quite so many words. However, the comparison to the cued-recall condition demonstrated that apparent memory failures were largely a result of retrieval rather than storage failures.
Categorization dramatically can affect retrieval. Investigators had participants learn lists of categorized words (Bower & associates, 1969). Either the words were presented in random order or they were presented in the form of a hierarchical tree that showed the organization of the words. For example, the category “minerals” might be at the top, followed by the categories of “metals and stones,” and so on. Participants given hierarchical presentation recalled 65% of the words. In contrast, recall was just 19% by participants given the words in random order.

A number of studies have used probability models to try to separate storage and retrieval. These models find probabilities that an item was stored or retrieved, based on participants’ responses to a number of questions (Chechile 2004; Chechile & Soraci, 1999). The models tend to be quite complex and require many hundreds of trials to be accurate. Therefore, these models tend to be limited in application to use of memory outside the laboratory. In one study described by Chechile, participants learned three words and then were tested on these words. Chechile was able to show differences in retrieval by changing how much time the participant had to recall the item. When there was very little time per item, fewer items were recalled. When the participant had more time, more of the items were recalled (Chechile, 2004). Participants could not retrieve items quickly enough in the “little-time” condition.

Another problem that arises when studying memory is figuring out why we sometimes have trouble retrieving information. Cognitive psychologists often have difficulty finding a way to distinguish between availability and accessibility of items. **Availability** is the presence of information stored in long-term memory. **Accessibility** is the degree to which we can gain access to the available information. Memory performance depends on the accessibility of the information to be remembered. Ideally, memory researchers would like to assess the availability of information in memory. Unfortunately, they must settle for assessing the accessibility of such information.

### Processes of Forgetting and Memory Distortion

Why do we so easily and so quickly forget phone numbers we have just looked up or the names of people whom we have just met? Several theories have been proposed as to why we forget information stored in working memory. The two most well-known theories are interference theory and decay theory. **Interference** occurs when competing information causes us to forget something; **decay** occurs when simply the passage of time causes us to forget.

#### Interference versus Decay Theory

**Interference theory** refers to the view that forgetting occurs because recall of certain words interferes with recall of other words. Evidence for interference goes back many years (Brown, 1958; Peterson & Peterson, 1959). In one study, participants to recall trigrams (strings of three letters) at intervals of 3, 6, 9, 12, 15, or 18 seconds after the presentation of the last letter (Peterson & Peterson, 1959). The investigator used
only consonants so that the trigrams would not be easily pronounceable—for example, “K B F.” Figure 6.2 shows percentages of correct recalls after the various intervals of time. Why does recall decline so rapidly? Because after the oral presentation of each trigram, participants counted backward by threes from a three-digit number spoken immediately after the trigram. The purpose of having the participants count backward was to prevent them from rehearsing during the *retention interval*. This is the time between the presentation of the last letter and the start of the recall phase of the experimental trial.

Clearly, the trigram is almost completely forgotten after just 18 seconds if participants are not allowed to rehearse it. Moreover, such forgetting also occurs when words rather than letters are used as the stimuli to be recalled (Murdock, 1961). Thus, counting backward interfered with recall from short-term memory, supporting the interference account of forgetting in short-term memory. At that time, it seemed surprising that counting backward with numbers would interfere with the recall of letters. The previous view had been that verbal information would interfere only with verbal (words) memory. Similarly, it was thought that quantitative (numerical) information would interfere only with quantitative memory.

Although the foregoing discussion has construed interference as though it were a single construct, at least two kinds of interference figure prominently in psychological theory and research: retroactive interference and proactive interference. Retroactive interference (or retroactive inhibition) is caused by activity occurring *after* we learn something but *before* we are asked to recall that thing. The interference in the Brown-Peterson task appears to be retroactive because counting backward by threes occurs after learning of the trigram. It interferes with our ability to remember information we learned previously.
A second kind of interference is **proactive interference** (or proactive inhibition). **Proactive interference** occurs when the interfering material occurs before, rather than after, learning of the to-be-remembered material. Proactive as well as retroactive interference may play a role in short-term memory (Keppel & Underwood, 1962). Thus, proactive interference appears to be important (Reitman, 1971; Shiffrin, 1973; Waugh & Norman, 1965), but not the only factor.

Some early psychologists recognized the need to study memory retrieval for connected texts and not just for unconnected strings of digits, words, or nonsense syllables. In one study, participants learned a text and then recalled it (Bartlett, 1932). Participants in Britain learned what was to them a strange and difficult-to-understand North American Indian legend called “The War of the Ghosts.” (The text is depicted in its entirety in Table 6.3.)

Participants distorted their recall to render the story more comprehensible to themselves. In other words, their prior knowledge and expectations had a substantial effect on their recall. Apparently, people bring into a memory task their already existing schemas, or organized relevant knowledge structures, which affect the way in which they recall what they learn. The later work using the Brown-Peterson paradigm confirms the notion that prior knowledge has an enormous effect on memory, sometimes leading to interference or distortion.

Yet another method often used for determining the causes of forgetting draws inferences from a serial-position curve: The serial-position curve represents the probability of recall of a given word, given its serial position (order of presentation) in a list. Suppose that you are presented with a list of words and are asked to recall them. You even might try it on yourself with the “Investigating Cognitive Psychology” box.

Say the following list of words once to yourself, and then, immediately thereafter, try to recall all the words, in any order, without looking back at them: *Table, Cloud, Book, Tree, Shirt, Cat, Light, Bench, Chalk, Flower, Watch, Bat, Rug, Soap, Pillow.*

If you are like most people, you will find that your recall of words is best for items at and near the end of the list. Your recall will be second best for items near the beginning of the list and poorest for items in the middle of the list. A typical serial-position curve is shown in Figure 6.3.

The **recency effect** refers to superior recall of words at and near the end of a list. The **primacy effect** refers to superior recall of words at and near the beginning of a list. As Figure 6.3 shows, both the recency effect and the primacy effect seem to influence recall. The serial-position curve makes sense in terms of interference theory. Words at the end of the list are subject to proactive but not to retroactive interference. Words at the beginning of the list are subject to retroactive but not to proactive interference. And words in the middle of the list are subject to both types of interference. Hence, recall would be expected to be poorest in the middle of the list. Indeed, it is poorest.

The amount of proactive interference generally climbs with increases in the length of time between when the information is presented (and encoded) and when
the information is retrieved (Underwood, 1957). Also as you might expect, proactive interference increases as the amount of prior—and potentially interfering—learning increases (Greenberg & Underwood, 1950).

Proactive interference seems to be associated with activation in the frontal cortex. In particular, it activates Brodmann area 45 in the left hemisphere (Postle, Brush, & Nick, 2004). In alcoholic patients, proactive interference is seen to a lesser degree.
than in nonalcoholic patients. This finding suggests that the alcoholic patients have difficulty integrating past information with new information. Thus, alcoholic patients may have difficulty binding together unrelated items in a list (De Rosa & Sullivan, 2003). Taken together, these findings suggest that Brodmann area 45 is likely involved in the binding of items into meaningful groups. When more information is gathered, an attempt to relate them to one another can occupy much of the available resources, leaving limited processing ability for new items.

All information does not equally contribute to proactive interference. For instance, if you are learning a list of numbers, your performance in learning the list will gradually decline as the list continues. If, however, the list switches to words, your performance will rebound. This enhancement in performance is known as release from proactive interference (Bunting, 2006). The effects of proactive interference appear to dominate under conditions in which recall is delayed. However, proactive and retroactive interference now are viewed as complementary phenomena.

Yet another theory for explaining how we forget information is decay theory. Decay theory asserts that information is forgotten because of the gradual disappearance, rather than displacement, of the memory trace. Thus, decay theory views the original piece of information as gradually disappearing unless something is done to keep it intact. This view contrasts with interference theory, just discussed, in which one or more pieces of information block recall of another.

Decay theory turns out to be exceedingly difficult to test. Why? First, under normal circumstances, preventing participants from rehearsing is difficult. Through rehearsal, participants maintain the to-be-remembered information in memory. Usually participants know that you are testing their memory. They may try to rehearse the information or they may even inadvertently rehearse it to perform well during testing. However, if you do prevent them from rehearsing, the possibility of interference arises. The task you use to prevent rehearsal may interfere retroactively with the original memory.
For example, try not to think of white elephants as you read the next two pages. When instructed not to think about them, you actually find it quite difficult not to. The difficulty persists even if you try to follow the instructions. Unfortunately, as a test of decay theory, this experiment is itself a white elephant because preventing people from rehearsing is so difficult.

Despite these difficulties, it is possible to test decay theory. Such a test involves using a task intervening between learning and testing that (1) prevents rehearsal and (2) presents no interfering learning. In one such study, the intervening task, involving tone detection, required a great deal of effort and attention but no new learning (Reitman, 1971, 1974). Participants heard a very faint tone presented through earphones. They were to press a button each time they heard the tone. Of course, there was no guarantee that participants would not rehearse at all. Nor was there any guarantee that all information would be blocked from entering short-term memory. However, the test was about as close to ideal as one could realistically produce.

Participants saw five words (Reitman, 1974). The display lasted for 2 seconds. As soon as the display went off, participants engaged in the tone-detection task for 15 seconds, after which they tried to recall as many of the five words as they could. Recall declined by about 24% over the 15 seconds. Reitman interpreted this decline as evidence of decay.

To conclude, evidence exists for both interference and decay, at least in short-term memory. The evidence for decay is not airtight, but it is certainly suggestive. The evidence for interference is rather strong. However, the extent to which the interference is retroactive, proactive, or both is unclear. In addition, interference also affects material in long-term memory, leading to memory distortion.

The Constructive Nature of Memory

An important lesson about memory is that memory retrieval is not just reconstructive, involving the use of various strategies (e.g., searching for cues, drawing inferences) for retrieving the original memory traces of our experiences and then rebuilding the original experiences as a basis for retrieval (see Kolodner, 1983, for an artificial-intelligence model of reconstructive memory). Rather, in real-life situations, memory is also constructive, in that prior experience affects how we recall things and what we actually recall from memory (Grant & Ceci, 2000; Sutton, 2003). Think back to the Bransford and Johnson (1972) study, cited at the opening of this chapter. In this study, participants could remember a passage about washing clothes quite well but only if they realized that it was about washing clothes.

In a further demonstration of the constructive nature of memory, participants read an ambiguous passage that could be interpreted meaningfully in two ways (Bransford & Johnson, 1973). Either it could be viewed as being either about watching a peace march from the fortieth floor of a building or about a space trip to an inhabited planet. Participants omitted different details, depending on what they thought the passage was about. Consider, for example, a sentence mentioning that the atmosphere did not require the wearing of special clothing. Participants were more likely to remember it when they thought the passage was about a trip into outer space than when they thought it was about a peace march.
Consider a comparable demonstration in a different domain (Bower, Karlin, & Dueck, 1975). Investigators showed participants 28 different droodles—nonsense pictures that can be given various interpretations (see also Chapter 10). Half of the participants in their experiment were given an interpretation by which they could label what they saw. The other half did not receive an interpretation prompting a label. Participants in the label group correctly reproduced almost 20% more droodles than did participants in the control group.

**Autobiographical Memory**

Autobiographical memory refers to memory of an individual's history. Autobiographical memory is constructive. One does not remember exactly what has happened. Rather, one remembers one's construction or reconstruction of what happened. People's autobiographical memories are generally quite good. Nevertheless, they are subject to distortions (as will be discussed later). They are differentially good for different periods of life. Middle-aged adults often remember events from their youthful and early-adult periods better than they remember events from their more recent past (Rubin, 1982, 1996).

One way of studying autobiographical memory is through diary studies. In such studies, individuals, often researchers, keep detailed autobiographies (e.g., Linton, 1982; Wagenaar, 1986). One investigator, for example, kept a diary for a 6-year period (Linton, 1982). She recorded at least two experiences per day on index cards. Then, each month she chose two cards at random and tried to recall the events she had written on the cards as well as the dates of the events. She further rated each memory for its salience and its emotional content. Surprisingly, her rate of forgetting of events was linear. It was not curvilinear, as is usually the case. In other words, a typical memory curve shows substantial forgetting over short time intervals and then a slowing in the rate of forgetting over longer time intervals. Linton's forgetting curve, however, did not show any such pattern. Her rate of forgetting was about the same over the entire 6-year interval. She also found little relationship between her ratings of the salience and emotionality of memories, on the one hand, and their memorability, on the other. Thus, she surprised herself in what she did and did not remember.

In another study of autobiographical memory, a researcher attempted to recall information regarding performances attended at the Metropolitan Opera over a period of 25 years (Sehulster, 1989). A total of 284 performances comprised the data for the study. The results were more in line with traditional expectations. Operas seen near the beginning and end of the 25-year period were remembered better (serial-position effect). Important performances also were better recalled than less important ones.

Recent work has illustrated the importance of self-esteem in the formation and recall of autobiographical memory. People with positive self-esteem remember more positive events, whereas people with negative self-esteem remember more negative events (Christensen, Wood, & Barrett, 2003).

**Memory Distortions**

People have tendencies to distort their memories (Ayers & Reder, 1998; Balota & associates, 1999; Garry & associates, 1996; Goff & Roediger, 1998; Heaps & Nash, 1999; Johnson & Raye, 1998; Norman & Schacter, 1997; Roediger & McDermott, 2000).
For example, just saying something has happened to you makes you more likely to think it really happened. This is true whether the event happened or not (Ackil & Zaragoza, 1998). These distortions tend to occur in seven specific ways, which Schacter (2001) refers to as the “seven sins of memory.” Here are Schacter’s “seven sins”:

1. **Transience.** Memory fades quickly. For example, although most people know that O. J. Simpson was acquitted of criminal charges in the murder of his wife, they do not remember how they found out about his acquittal. At one time they could have said, but they no longer can.

2. **Absent-mindedness.** People sometimes brush their teeth after already having brushed them or enter a room looking for something only to discover that they have forgotten what they were seeking.

3. **Blocking.** People sometimes have something that they know they should remember, but they can’t. It’s as though the information is on the tip of their tongue, but they cannot retrieve it. For example, people may see someone they know but the person’s name escapes them. Or they may try to think of a synonym for a word, knowing that there is an obvious synonym but are unable to recall it.

4. **Misattribution.** People often cannot remember where they heard what they heard or read what they read. Sometimes people think they saw things they did not see or heard things they did not hear. For example, eyewitness testimony is sometimes clouded by what we think we should have seen, rather than what we actually saw.

5. **Suggestibility.** People are susceptible to suggestion, so if it is suggested to them that they saw something, they may think they remember seeing it. For example, in Holland, when asked whether they had seen a television film of a plane crashing into an apartment building, many people said they had seen it. There was no such film.

6. **Bias.** People often are biased in their recall. For example, people who currently are experiencing chronic pain in their lives are more likely to remember pain in the past, whether or not they actually experienced it. People who are not experiencing such pain are less likely to recall pain in the past, again with little regard to their actual past experience.

7. **Persistence.** People sometimes remember things as consequential that, in a broad context, are inconsequential. For example, someone with many successes but one notable failure may remember the single failure better than the many successes.

What are some of the specific ways in which memory distortions are studied?

**The Eyewitness Testimony Paradigm**

A survey of U.S. prosecutors estimated that about 77,000 suspects are arrested each year after being identified by eyewitnesses (Dolan, 1995). Studies of more than 1000 known wrongful convictions have pointed to errors in eyewitness identification as
being “the single largest factor leading to those false convictions” (Wells, 1993, p. 554). What proportion of eyewitness identifications are mistaken? The answer to that question varies widely (“from as low as a few percent to greater than 90%; Wells, 1993, p. 554), but even the most conservative estimates of this proportion suggest frightening possibilities.

Consider the story of a man named Timothy. In 1986, Timothy was convicted of brutally murdering a mother and her two young daughters (Dolan, 1995). He was then sentenced to die, and for 2 years and 4 months, Timothy lived on death row. Although the physical evidence did not point to Timothy, eyewitness testimony placed him near the scene of the crime at the time of the murder. Subsequently, it was discovered that a man who looked like Timothy was a frequent visitor to the neighborhood of the murder victims, and Timothy was given a second trial and was acquitted.

Some of the strongest evidence for the constructive nature of memory has been obtained by those who have studied the validity of eyewitness testimony. In a now classic study, participants saw a series of 30 slides in which a red Datsun drove down a street, stopped at a stop sign, turned right, and then appeared to knock down a pedestrian crossing at a crosswalk (Loftus, Miller, & Burns, 1978). As soon as the participants finished seeing the slides, they had to answer a series of 20 questions about the accident. One of the questions contained information that was either consistent or inconsistent with what they had been shown. For example, half the participants were asked: “Did another car pass the red Datsun while it was stopped at the stop sign?” The other half of the participants received the same question, except with the word *yield* replacing the word *stop*. In other words, the information in the question given this second group was inconsistent with what the participants had seen.

Later, after engaging in an unrelated activity, all participants were shown two slides and asked which they had seen. One had a stop sign, the other had a yield sign. Accuracy on this task was 34% better for participants who had received the consistent question (stop sign question) than for participants who had received the inconsistent question (yield sign question). This experiment and others (e.g., Loftus, 1975; 1977) have shown people’s great susceptibility to distortion in eyewitness accounts. This distortion may be due, in part, to phenomena other than just constructive memory. But it does show that we easily can be led to construct a memory that is different from what really happened. As an example, you might have had a disagreement with a roommate or a friend regarding an experience in which both of you were in the same place at the same time. But what each of you remembers about the experience may differ sharply. And *both* of you may feel that you are truthfully and accurately recalling what happened.

There are serious potential problems of wrongful conviction when using eyewitness testimony as the sole or even the primary basis for convicting accused people of crimes (Loftus & Ketcham, 1991; Loftus, Miller, & Burns, 1987; Wells & Loftus, 1984). Moreover, eyewitness testimony is often a powerful determinant of whether a jury will convict an accused person. The effect particularly is pronounced if eyewitnesses appear highly confident of their testimony. This is true even if the eyewitnesses can provide few perceptual details or offer apparently conflicting responses. People sometimes even think they remember things simply because they have imagined or thought about them (Garry & Loftus, 1994). It has been estimated that as many as 10,000 people per year may be convicted wrongfully on the basis of mistaken eyewitness testimony (Cutler &
Penrod, 1995; Loftus & Ketcham, 1991). In general, then, people are remarkably susceptible to mistakes in eyewitness testimony. In general, they are prone to imagine that they have seen things they have not seen (Loftus, 1998).

Lineups can lead to faulty conclusions (Wells, 1993). Eyewitnesses assume that the perpetrator is in the lineup. This is not always the case, however. When the perpetrator of a staged crime was not in a lineup, participants were susceptible to naming someone other than the perpetrator as the perpetrator. In this way, they can recognize someone in the lineup as having committed the crime. The identities of the nonperpetrators in the lineup also can affect judgments (Wells, Luus, & Windschitl, 1994). In other words, whether a given person is identified as a perpetrator can be influenced simply by who the others in the lineup are. So the choice of the “distracter” individuals is important. Police may inadvertently affect the likelihood of whether an identification occurs or not and also whether a false identification is likely to occur.

Eyewitness identification is particularly weak when identifying people of a race other than the race of the witness (e.g., Bothwell, Brigham, & Malpass, 1989; Brigham & Malpass, 1985; Pezdek, Blandon-Gitlin, & Moore, 2003; Shapiro & Penrod, 1986). Evidence suggests that this is not a result of problems remembering stored

**IN THE LAB OF ELIZABETH LOFTUS**

Remember the time when you were a kid and your family went to Disneyland? The highlight of your trip was meeting Mickey Mouse, who shook your hand? Remember that? Marketers use autobiographical advertising like this to create nostalgia for their products. Several years ago, we wondered whether such referencing could cause people to believe that they had experiences as children that are mentioned in the ads (Braun, Ellis, & Loftus, 2002). In our first study, participants viewed an ad for Disneyland that suggested that as a child they shook hands with Mickey Mouse. Later on they answered questions about their childhood experiences at Disneyland. Relative to controls, the ad increased their confidence that they personally had shaken hands with Mickey at Disneyland.

Of course we realized that the increased confidence could be due to either (1) a revival of a true memory or (2) the creation of a new, false one. Because some people could have actually met Mickey at Disney, both are possibilities. So, we conducted a second study in which our participants viewed a fake ad for Disneyland that suggested that they shook hands with an impossible character: Bugs Bunny. Of course, Bugs is a Warner Brothers character and would not be found at a Disney resort. Again, relative to controls, the ad increased confidence that they personally had shaken hands with the impossible character as a child at Disneyland. Although this could not possibly have happened because Bugs Bunny is a Warner Brothers character and would not be caught dead at a Disney property, about 16% of the subjects later said that they remembered or knew that the event actually had happened to them. In another study, we showed that having a picture of Bugs mattered. Even more people claimed to have met Bugs when a picture of Bugs was included in the ad than when Bugs was only described verbally. False memories of Bugs in one condition were as high as 48% (Braun-LaTour & associates, 2004).

We wondered whether it was the advertisement itself that was producing the false memory, or whether any recent exposure to Bugs Bunny would produce a similar effect. For example, if people recently had seen Bugs in a Bugs Bunny cartoon, would they also claim later that they had met Bugs on a childhood trip to Disneyland? In one series of studies, people did not
faces of people from other races, but rather, of encoding these faces (Walker & Tanaka, 2003). Even infants seem to be influenced by post-event information when recalling an experience, as shown through their behavior in operant-conditioning experiments (Rovee-Collier & associates, 1993).

Eyewitness identification and recall are also affected by the witness’s level of stress. As stress increases, the accuracy of both recall and identification declines (Dffenbacher & associates, 2004; Payne & associates, 2002). These findings further call into question the accuracy of eyewitness testimony because most crimes occur in highly stressful situations.

Not everyone views eyewitness testimony with such skepticism, however (e.g., see Zaragoza, McCloskey, & Jamis, 1987). It is still not clear whether the information about the original event actually is displaced by, or is simply competing with, the subsequent misleading information. Some investigators have argued that psychologists need to know a great deal more about the circumstances that impair eyewitness testimony before impugning such testimony before a jury (McKenna, Treadway, & McCloskey, 1992). At present, the verdict on eyewitness testimony is still not in. The same can be said for repressed memories, considered in the next section.

IN THE LAB OF ELIZABETH LOFTUS—cont’d

claim to have met Bugs if they had recently seen a large cardboard cutout of him; they only claimed to have done so if exposed to the doctored ad (Pickrell, 2005).

It’s one thing to plant a false memory of meeting Bugs Bunny, but quite another to plant a false memory of an unpleasant experience with another character. So with Shari Berkowitz and other colleagues, we tried to plant a false belief that people had had an unpleasant experience with the Pluto character while on a childhood trip to Disney (Berkowitz & associates, 2008). We succeeded with about 30% of the subjects. Moreover, those who were seduced by the suggestion did not want to pay as much for a Pluto souvenir. This finding shows that false beliefs can have consequences—they can affect later thoughts and behaviors.

These studies are part of a larger program of research on the malleability of human memory (Loftus, 2005). But more specifically, these findings suggest that advertisements that contain autobiographical referencing can tamper with our personal childhood memories. Although advertisers are probably not mentioning false details, they do mention details that could be true. However, they are not true for everyone. You may have seen a picture of Mickey Mouse when you were at Disneyland, but you never actually met him or shook hands with him. An ad may make you think you did. Because we view thousands of advertisements in the course of a typical month, could we all be unwitting subjects in a mass experiment on memory distortion?

References
Whatever may be the validity of eyewitness testimony for adults, it clearly is suspect for children (Ceci & Bruck, 1993, 1995). Children’s recollections are particularly susceptible to distortion. Such distortion is especially likely when the children are asked leading questions, as in a courtroom setting. Consider some relevant facts (Ceci & Bruck, 1995). First, the younger the child is, the less reliable the testimony of that child can be expected to be. In particular, children of preschool age are much more susceptible to suggestive questioning that tries to steer them to a certain response than are school-age children or adults. Second, when a questioner is coercive or even just seems to want a particular answer, children can be quite susceptible to providing the adult with what he or she wants to hear. Given the pressures involved in court cases, such forms of questioning may be unfortunately prevalent. For instance, when asked a yes-or-no question, even if they don’t know the answer, most children will give an answer. If the question has an explicit “I don’t know” option, most children, when they do not know an answer, will admit they do not know rather than speculate (Waterman, Blades, & Spencer, 2001). Third, children may believe that they recall observing things that others have said they observed. In other words, they hear a story about something that took place and then believe that they have observed what allegedly took place. If the child has some intellectual disability, memory for the event is even more likely to be distorted, at least when a significant delay has occurred between the time of the event and the time of recall (Henry & Gudjonsson, 2003). Perhaps even more than eyewitness testimony from adults, the testimony of children must be interpreted with great caution.

Steps can be taken to enhance eyewitness identification (e.g., using methods to reduce potential biases, to reduce the pressure to choose a suspect from a limited set of options, and to ensure that each member of an array of suspects fits the description given by the eyewitness, yet offers diversity in other ways; described in Wells, 1993). Research also indicates that suggestive interviews can cause biases in memory (Melnyk & Bruck, 2004). This is especially likely when these interviews take place close in time to the actual event. After a crime, the witnesses are generally interviewed as soon as possible. Therefore, steps must be taken to ensure that the questions asked of witnesses are not leading questions, especially when the witness is a child. This caution can decrease the likelihood of distortion of memory. In addition, some psychologists (e.g., Loftus, 1993a, 1993b) and many defense attorneys believe that jurors should be advised that the degree to which the eyewitness feels confident of her or his identification does not necessarily correspond to the degree to which the eyewitness is actually accurate in her or his identification of the defendant as being the culprit. At the same time, some psychologists (e.g., Egeth, 1993; Yuille, 1993) and many prosecutors believe that the existing evidence, based largely on simulated eyewitness studies rather than on actual eyewitness accounts, is not strong enough to risk attacking the credibility of eyewitness testimony when such testimony might send a true criminal to prison, preventing the person from committing further crimes.

**Repressed Memories**

Might you have been exposed to a traumatic event as a child but have been so traumatized by this event that you now cannot remember it? Some psychotherapists have begun using hypnosis and related techniques to elicit from people what are alleged to be repressed memories. Repressed memories are memories that are alleged to have
been pushed down into unconsciousness because of the distress they cause. Such memories, according to the view of psychologists who believe in their existence, are very inaccessible, but they can be dredged out (Briere & Conte, 1993).

Do repressed memories actually exist? Many psychologists strongly doubt their existence (Ceci & Loftus, 1994; Lindsay & Read, 1994; Loftus & Ketcham, 1994; Pennebaker & Memon, 1996; Roediger & McDermott, 1995, 2000). Others are at least highly skeptical (Bowers & Farvolden, 1996; Brenneis, 2000). There are many reasons for this skepticism, which are provided in the following section. First, some therapists may be inadvertently planting ideas in their clients’ heads. In this way, they may be creating false memories of events that never took place. Indeed, creating false memories is relatively easy, even in people with no particular psychological problems. Such memories can be implanted by using ordinary, nonemotional stimuli (Roediger & McDermott, 1995). Second, showing that implanted memories are false is often extremely hard to do. Reported incidents often end up, as in the case of childhood sexual abuse, merely pitting one person’s word against another (Schooler, 1994). At the present time, no compelling evidence points to the existence of such memories. But psychologists also have not reached the point where their existence can be ruled out definitively. Therefore, no clear conclusion can be reached at this time.

The Roediger-McDermott (1995) paradigm, which is adapted from work of Deese (1959), is able to show the effects of memory distortion in the laboratory. Participants receive a list of 15 words strongly associated with a critical but nonpresented word. For example, the participants might receive 15 words strongly related to the word sleep but never receive the word sleep. The recognition rate for the nonpresented word (in this case, sleep) was comparable to that for presented words. This result has been replicated multiple times (McDermott, 1996; Schacter, Verfaellie, & Pradere, 1996; Sugrue & Hayne, 2006). Even when shorter lists were used, there was an increased level of false recognition for nonpresented items. In one experiment, lists as short as three items revealed this effect, although to a lesser degree (Coane & associates, 2007). Embedding the list in a story can increase this effect in young children. This strategy strengthens the shared context and increases the probability of a participant’s falsely recognizing the nonpresented word (Dewhurst, Pursglove, & Lewis, 2007).

Why are people so weak in distinguishing what they have heard from what they have not heard? One possibility is a source-monitoring error, which occurs when a person attributes a memory derived from one source to another source. Research by Marcia Johnson and her colleagues (Johnson, 1996; Johnson, Hashtroudi, & Lindsay, 1993; Lindsay & Johnson, 1991) suggests that people frequently have difficulties in source monitoring, or figuring out the origins of a memory. They may believe they read an article in a prestigious newspaper, such as the New York Times, when in fact they saw it in a tabloid on a supermarket shelf while waiting to check out. When people hear a list of words not containing a word that is highly associated with the other words, they may believe that their recall of that central word is from the list rather than from their minds.

Another possible explanation of this increased false recognition is spreading activation. In spreading activation, every time an item is studied, you think of the items related to that item. Imagine a metaphorical spider web with a word in the middle. Branching out from that word are all the words relating to that word. There will of course be individual differences in the construction of these webs, but there will also
be a lot of overlap. For instance, when you read the word nap, words like sleep, bed, and cat may be activated in your mind. In this way, activation branches out from the original word nap. If you see 15 words, all of which activate the word sleep, it is likely that, via a source-monitoring error, you may think you had been presented the word sleep. Some recent work supports the spreading-activation theory of errors in this paradigm (Dodd & MacLeod, 2004; Hancock & associates, 2003; Roediger, Balota, & Watson, 2001). This theory is not, however, universally accepted (Meade & associates, 2007).

**Context Effects on Encoding and Retrieval**

As studies of constructive memory show, our cognitive contexts for memory clearly influence our memory processes of encoding, storing, and retrieving information. Studies of expertise also show how existing schemas may provide a cognitive context for encoding, storing, and retrieving new information. Specifically, experts generally have more elaborated schemas than do novices in regard to their areas of expertise (e.g., Chase & Simon, 1973; Frensch & Sternberg, 1989). These schemas provide a cognitive context in which the experts can operate. The use of schemas makes integration and organization relatively easy. They fill in gaps when provided with partial or even distorted information and visualize concrete aspects of verbal information. They also can implement appropriate metacognitive strategies for organizing and rehearsing new information. Clearly, expertise enhances our confidence in our recollected memories.

Another factor that enhances our confidence in recall is the perceived clarity—the vividness and richness of detail—of the experience and its context. When we are recalling a given experience, we often associate the degree of perceptual detail and intensity with the degree to which we are accurately remembering the experience (Johnson & associates, 1988; Johnson, Hashtroudi, & Lindsay, 1993; Johnson, Nolde, & De Leonards, 1996; Johnson & Raye, 1981). We feel greater confidence that our recollections are accurate when we perceive them with greater richness of detail. Although this heuristic for reality monitoring is generally effective, there are some situations in which factors other than accuracy of recall may lead to enhanced vividness and detail of our recollections (Neisser, 1982). When you can recall the context of the learning experience, there is an increased activation of the hippocampus (Eldridge & associates, 2000). Events that involve emotional stimuli also produce an increased activation in the amygdala. This activation leads to an enhancement of explicit memory (Milner, Squire, & Kandel, 1998; Roberson-Nay & associates, 2006). Interestingly, electrical stimulation of either the hippocampus or the amygdala can lead to recall and even hallucinations of autobiographical memories (Vignal & associates, 2007).

In particular, an oft-studied form of vivid memory is the flashbulb memory—a memory of an event so powerful that the person remembers the event as vividly as if it were indelibly preserved on film (Brown & Kulik, 1977). People old enough to recall the assassination of President John Kennedy may have flashbulb memories of this event. Some people also have flashbulb memories for the explosion of the space shuttle Challenger, the destruction of the World Trade Center on 9/11, or momentous events in their personal lives. The emotional intensity of an experience may enhance the likelihood that we will recall the particular experience (over other experiences) ardently and perhaps accurately (Bohannon, 1988). A related view is that a memory
is most likely to become a flashbulb memory under three circumstances. These are that the memory trace is important to the individual, is surprising, and has an emotional effect on the individual (Conway, 1995).

Some investigators suggest that flashbulb memories may be more vividly recalled because of their emotional intensity. Other investigators, however, suggest that the vividness of recall may be the result of the effects of rehearsal. The idea here is that we frequently retell, or at least silently contemplate, our experiences of these momentous events. Perhaps our retelling also enhances the perceptual intensity of our recall (Bohannon, 1988). Other findings suggest that flashbulb memories may be perceptually rich (Neisser & Harsch, 1993). In this view, they may be recalled with relatively greater confidence in the accuracy of the memories (Weaver, 1993) but not actually be any more reliable or accurate than any other recollected memory (Neisser & Harsch, 1993; Weaver, 1993). Suppose flashbulb memories are indeed more likely to be the subject of conversation or even silent reflection. Then perhaps, at each retelling of the experience, we reorganize and construct our memories such that the accuracy of our recall actually diminishes while the perceived vividness of recall increases over time. At present, researchers heatedly debate whether studies of such memories as a special process are a flash in the pan (e.g., Cohen, McCloskey, & Wible, 1990) or a flash of insight into memory processes (e.g., Schmidt & Bohannon, 1988).

Some interesting effects of flashbulb memory involve the role of emotion. The more a person is emotionally involved in an event, the better the person’s memory for that event is. Also, over time, memory for the event degrades (Smith, Bibi, & Sheard, 2004). In one study, more than 70% of people questioned reported seeing on September 11, 2001, the day of the World Trade Center attacks, the first plane hit the first tower. However, this footage was not available until the next day (Pezdek, 2003, 2006). Thus, they could not have seen on September 11 the footage of the plane hitting the tower. These distortions illustrate the constructive nature of flashbulb memories. These findings further indicate that flashbulb memories are not immune to distortion, as once was thought.

The emotional intensity of a memorable event is not the only way in which emotions, moods, and states of consciousness affect memory. Our moods and states of consciousness also may provide a context for encoding that affects later retrieval of semantic memories. Thus, when we encode semantic information during a particular mood or state of consciousness, we may more readily retrieve that information when in the same state again (Baddeley, 1989; Bower, 1983). Regarding state of consciousness, something that is encoded when we are influenced by alcohol or other drugs may be retrieved more readily while under those same influences again (Eich, 1980, 1995). On the whole, however, the “main effect” of alcohol and many drugs is stronger than the interaction. In other words, the depressing effect of alcohol and many drugs on memory is greater than the facilitating effect of recalling something in the same drugged state as when one encoded it.

In regard to mood, some investigators have suggested a factor that may maintain depression. In particular, the depressed person can more readily retrieve memories of previous sad experiences, which may further the continuation of the depression (Baddeley, 1989). If psychologists or others can intervene to prevent the continuation of this vicious cycle, the person may begin to feel happier. As a result, other happy memories may be more easily retrieved, thus further relieving the depression, and so on. Perhaps the folk-wisdom advice to “think happy thoughts” is not entirely unfounded. In fact,
under laboratory conditions, participants seem more accurately to recall items that have pleasant associations than they recall items that have unpleasant associations (Matlin & Underhill, 1979). Interestingly, people suffering from depression tend to have deficits in forming and recalling memories (Bearden & associates, 2006).

Emotions, moods, states of consciousness, schemas, and other features of our internal context clearly affect memory retrieval. In addition, even our external contexts may affect our ability to recall information. We appear to be better able to recall information when we are in the same physical context as the one in which we learned the material (Godden & Baddeley, 1975). In one experiment, 16 underwater divers were asked to learn a list of 40 unrelated words. Learning occurred either while the divers were on shore or while they were 20 feet beneath the sea. Later, they were asked to recall the words when either in the same environment as where they had learned them or in the other environment. Recall was better when it occurred in the same place as did the learning.

Even infants demonstrate context effects on memory. Consider an operant-conditioning experiment in which the infants could make a crib mobile move in interesting ways by kicking it. Three month olds (Butler & Rovee-Collier, 1989) and 6 month olds (Borovsky & Rovee-Collier, 1990) were given an opportunity to kick a distinctive crib mobile in the same context (i.e., surrounded by a distinctive bumper lining the periphery of the crib) in which they first learned to kick it or in a different context. They kicked more strongly in the same context. The infants showed much less kicking when in a different context or when presented with a different mobile.

From these results, such learning seems highly context dependent. However, in one set of studies, 3-month-olds (Rovee-Collier & DuFault, 1991) and 6-month-olds (Amabile & Rovee-Collier, 1991) were offered operant-conditioning experiences in multiple contexts for kicking a distinctive mobile. They were soon thereafter placed in a novel context. It was unlike any of the contexts for conditioning. The infants retained the memory. They kicked the mobile at high rates in the novel context. Thus, when information is encoded in various contexts, the information also seems to be retrieved more readily in various contexts. This effect occurs at least when there is minimal delay between the conditioning contexts and the novel context. However, consider what happened when the novel context occurred after a long delay. The infants did not show increased kicking. Nevertheless, they still showed context-dependent memory for kicking in the familiar contexts (Amabile & Rovee-Collier, 1991).

All of the preceding context effects may be viewed as an interaction between the context for encoding and the context for retrieval of encoded information. The results of various experiments on retrieval suggest that how items are encoded has a strong effect both on how and on how well items are retrieved. This relationship is called encoding specificity—what is recalled depends on what is encoded (Tulving & Thomson, 1973). Consider a rather dramatic example of encoding specificity. We know that recognition memory is virtually always better than recall. For example, recognizing a word that you have learned is easier than recalling it. After all, in recognition you have only to say whether you have seen the word. In recall, you have to generate the word and then mentally confirm whether it appeared on the list.

In one experiment, Watkins and Tulving (1975) had participants learn a list of 24 paired associates, such as ground-cold and crust-cake. Participants were instructed to learn to associate each response (such as cold) with its stimulus word (such as ground). After participants had studied the word pairs, they were given an irrelevant
task. Then they were given a recognition test with distracters. Participants were asked simply to circle the words they had seen previously. Participants recognized an average of 60% of the words from the list. Then, participants were provided with the 24 stimulus words. They were asked to recall the responses. Their cued recall was 73%. Thus, recall was better than recognition. Why? According to the encoding-specificity hypothesis, the stimulus was a better cue for the word than the word itself. The reason was that the words had been learned as paired associates.

As mentioned previously (see Chapter 5), the link between encoding and retrieval also may explain the self-reference effect (Greenwald & Banaji, 1989). Specifically, the main cause of the self-reference effect is not due to unique properties of self-referent cues. Rather, it is due to a more general principle of encoding and retrieval: When individuals generate their own cues for retrieval, they are much more potent than when other individuals do so. Other researchers have confirmed the importance of making cues meaningful to the individual to enhance memory. For example, consider what happened when participants made up their own retrieval cues. They were able to remember, almost without errors, lists of 500 and 600 words (Mantyla, 1986). For each word on a list, participants were asked to generate another word (the cue) that to them was an appropriate description or property of the target word. Later, they were given a list of their cue words. They were asked to recall the target word. Cues were most helpful when they were both compatible with the target word and distinctive, in that they would not tend to generate a large number of related words. For example, if you are given the word coat, then jacket might be both compatible and distinctive as a cue. However, suppose you came up with the word wool as a cue. That cue might make you think of a number of words, such as fabric and sheep, that are not the target word.

To summarize, retrieval interacts strongly with encoding. Suppose you are studying for a test and want to recall well at the time of testing. Organize the information you are studying in a way that appropriately matches the way in which you will be expected to recall it. Similarly, you will recall information better if the level of processing for encoding matches the level of processing for retrieval (Moscovitch & Craik, 1976).

---

**Memory Development**

Many changes occur in memory with development (Bauer & Van Abbema, 2003). What are some of these changes?

**Metacognitive Skills and Memory Development**

Some researchers also have suggested that older children may have greater processing resources (Kail & Bisanz, 1992), such as attentional resources and working memory. These resources may underline the overall greater speed of cognitive processing of older children. According to this view, the reason that older children seem able to process information more quickly than younger children may be because the older children can hold more information for active processing. Hence, in addition to being able to organize information into increasingly large and complex chunks, older children may be able to hold more chunks of information in working memory.
Children appear to develop and use increasing metamemory skills and various other kinds of metacognitive skills. These skills involve the understanding and control of cognitive processes. Examples are monitoring and modifying one’s own cognitive processes while one is engaged in tackling cognitive tasks (Brown, 1978; Flavell & Wellman, 1977). Many information-processing researchers have been interested in the specific metacognitive skills of older children. An example is work on the understanding of appearance and reality. For example, 4- and 5-year-old children were shown imitation objects such as a sponge that looked exactly like a rock (Flavell, Flavell, & Green, 1983). The researchers encouraged the children to play with the imitations so they could become thoroughly familiar with the objects. In this way, the children would see clearly that the fakes were not what they appeared to be. Children then had to answer questions about the identity of the objects. Afterward, the children were asked to view the objects through a blue plastic sheet and to make color judgments about the objects. The sheet distorted the perceived hues of the objects. The children also were asked to make size judgments while viewing the objects through a magnifying glass. The children were fully aware that they were viewing the objects through these intermediaries.

The children’s errors formed an interesting pattern. There were two fundamental kinds of errors. When asked to report reality (the way the object actually was), the children would sometimes report appearance (the way the object looked through the blue plastic or the magnifying glass). When asked to report appearance, they would sometimes report the reality. In other words, 4- and 5-year-old children did not yet clearly perceive the distinction between appearance and reality.

Actually, many scholars would agree with the observation that young children often fail to distinguish appearance from reality. Their failure to conserve quantity also may be attributed to their attention to the change in appearance, rather than to the stability of the quantity. Children also increasingly profit from and eventually even seek out feedback regarding the outcomes of their cognitive efforts. These changes in encoding, memory organization and storage, metacognition, and use of feedback seem to affect children’s cognitive development across many specific domains. In addition, however, some cognitive-developmental changes seem to be domain specific.

The use of external memory aids, rehearsal, and many other memory strategies seems to come naturally to almost all of us as adults—so much so that we may take for granted that we have always done it; we have not. Lynne Appel and her colleagues (1972) designed an experiment to discover the extent to which young children spontaneously rehearse. They showed colored pictures of common objects to children at three grade levels: preschoolers, first-graders, and fifth-graders. Children were instructed either to “look at” the names of 15 pictures or to “remember” the names for a later test.

When children were instructed just to look at the pictures, almost no children exhibited rehearsal. In the memory condition, some of the young children showed some—but not much—rehearsal. Very few of the preschoolers seemed to know that rehearsing would be a good idea when they would later be asked to recall information. Moreover, the performance of the preschoolers was no better in the memory condition than in the looking condition.

Older children performed better. A major difference between the memory of younger and older children (as well as adults) is not in basic mechanisms, but in
learned strategies, such as rehearsal (Flavell & Wellman, 1977). Young children seriously overestimate their ability to recall information. They rarely spontaneously use rehearsal strategies when asked to recall items. That is, young children seem not to know about many memory-enhancing strategies.

In addition, even when young children do know about such strategies, they do not always use them. For example, even when trained to use rehearsal strategies in one task, most do not transfer the use of that strategy. They do not carry over their learning from one task to other tasks (Flavell & Wellman, 1977; Jarrold, Baddeley, & Hewes, 2000). Thus, young children appear to lack not only the knowledge of strategies but also the inclination to use them when they do know about them. Older children understand that to retain words in short-term memory, they need to rehearse. Younger children do not have this understanding. In a nutshell, younger children lack metamemory skills.

Whether children rehearse is not just a function of age. Mentally retarded children are much less likely to rehearse spontaneously than are children of normal intelligence (Brown & associates, 1973). Indeed, if such children are trained to rehearse, their performance can be improved greatly (Belmont & Butterfield, 1971; Butterfield, Wambold, & Belmont, 1973). However, the mentally retarded performers will not always spontaneously transfer their learning to other tasks. For example, if the children are taught to rehearse with lists of numbers but then are presented with a list of animals, they may have to be taught all over again to rehearse for the new kinds of items, as well as for the old. In children with attention deficit hyperactivity disorder, where memory impairments are frequently observed, there also seems to be an under-reliance on rehearsal (Kilingberg, Forssberg, & Westerberg, 2002).

Culture, experience, and environmental demands also affect the use of memory-enhancing strategies. For example, Western children generally have more formal schooling than do non-Western children. As a result, they are given much more practice using rehearsal strategies for remembering isolated bits of information. In contrast, Guatemalan children and Australian aboriginal children generally have many more opportunities to become adept at using memory-enhancing strategies that rely on spatial location and arrangements of objects (Kearins, 1981; Rogoff, 1986).

Another aspect of metamemory skill involves cognitive monitoring. In monitoring, the individual tracks and, as needed, readjusts an ongoing train of thought. Cognitive monitoring may consist of several related skills (Brown, 1978; see also Brown & DeLoache, 1978). For instance, you are realizing “what you know and what you do not know” (Brown, 1978, p. 82). You learn to be aware of your own mind and the degree of your own understanding (Holt, 1964). Other work on the development of cognitive monitoring proposes a distinction between self-monitoring and self-regulation strategies (Nelson & Narens, 1994). Self-monitoring is a bottom-up process of keeping track of current understanding, involving the improving ability to predict memory performance accurately. Self-regulation is a top-down process of central executive control over planning and evaluation. Children benefit from training in using such cognitive monitoring processes to enhance their use of appropriate strategies (see Schneider & Bjorklund, 1998).

Recall also that physiological maturation of the brain and increasing content knowledge may partially explain why adults and older children generally perform better on memory tests than do younger children. These physiological and experience-based changes augment the changes in memory processes. Examples are increased
knowledge about and inclination to use metamemory strategies. The goal of such strategies is to be able eventually to retrieve stored information at will.

An important metacognitive development is the acquisition of a theory of mind—that is, an understanding of how the mind operates (Keil, 1999; Perner, 1998, 1999). As children grow older, their theory of mind becomes more sophisticated. Consider an example (Perner, 1999, p. 207): “Maxi puts his chocolate into the cupboard. He goes out to play. While he is outside he can’t see that his mother comes and transfers the chocolate from the cupboard into the table drawer. She then leaves to visit a friend. When Maxi comes home to get his chocolate, where will he look for it?” Children below the age of 3 typically give the wrong answer, believing that Maxi will search for the chocolate in the drawer where it actually is. By age 3, some children start to get the problem right. By 4 years of age, most children solve the problem correctly, although even some 5 and 6 year olds still make errors (Ruffman & associates, 1998). Autistic children seem to lack or have a seriously defective theory of mind (Baron-Cohen, Leslie, & Frith, 1985; Perner, 1999).

Early development of theory of mind is related to verbal intelligence, communication abilities, and the number of siblings that a child has (McAlister & Peterson, 2007; Resches & Perez Pereira, 2007). This finding is not surprising, given that increased verbal and communication abilities and increased number of siblings are likely to increase the amount of interpersonal experience children have. Therefore, increased verbal abilities and number of siblings are likely to help the child to have increased ability to put himself or herself in another’s shoes.

Throughout late childhood and most of adulthood, memory abilities remain relatively constant. However, in many older adults, memory abilities begin to decline. Many studies have noted a decrease in the amount of new material and skills that can be learned as we age (Collie & associates, 2001; Tunney & associates, 2002). It is apparent that memory decline in older adults occurs as a result in changes in the frontal-striatal system. These changes include changes in white matter and depletion in neurotransmitters (Buckner, 2004). Also, a decrease in hippocampal activity is associated with decline in memory (Cabeza & associates, 2004). These changes are different from the brain changes that are observed in patients with Alzheimer’s disease (see Chapter 5).

This chapter and the previous chapter have indicated many situations in which knowledge and memory interact, such as when prior knowledge influences encoding and retrieval. The following two chapters describe how we represent knowledge. They emphasize the roles of mental imagery and semantic knowledge.

Key Themes

This chapter illustrates several of the key themes first presented in Chapter 1.

First, it highlights the issue of validity of causal inference versus ecological validity. Some researchers, such as Mahzarin Banaji and Robert Crowder, have argued that laboratory research yields findings that maximize not only experimental control but also ecological validity. Ulric Neisser has disagreed, suggesting that if one wishes to study everyday memory, one must study it in everyday settings. Ultimately, the two
kinds of research together are likely to maximize our understanding of memory phenomena. Typically, there is no one right way to do research. Rather, we learn the most when we use a variety of methods that converge on a set of common findings.

Secondly, the chapter raises the issue of domain specificity versus domain generality. Mnemonics discussed in this chapter work better in certain domains than they do in others. For example, you may be able to devise mnemonics better if you are highly familiar with a domain, such as was the case for the runner studied by Chase, Ericsson, and Faloon (discussed in Chapter 5). In general, the more knowledge you have about a domain, the easier it will be to chunk information in that domain.

Thirdly, the chapter raises an interesting issue of rationalism versus empiricism. This issue is the extent to which courts should rely on empirical evidence from psychological research to guide what they do. To what extent should the credibility of witnesses be determined by rational considerations (e.g., were they at the scene of a crime, or are they known to be trustworthy) and to what extent by empirical considerations revealed by psychological research (e.g., being at the scene of a crime does not guarantee credible testimony, and people’s judgments of trustworthiness are often incorrect)? Court systems often work on the basis of rational considerations—of what should be. Psychological research reveals what is.

Get some friends or family members to help you again. Tell them that you are going to read a list of words, and as soon as you finish, they are to write down as many words as they can remember in any order they wish. Read the following words to them about 1 second apart: book, peace, window, run, box, harmony, hat, voice, tree, begin, anchor, hollow, floor, area, tomato, concept, arm, rule, lion, hope. After giving them enough time to try to remember the words, total their number of recollections in the following groups of four: (1) book, peace, window, run; (2) box, harmony, hat, voice; (3) tree, begin, anchor, hollow; (4) floor, area, tomato, concept; (5) arm, rule, lion, hope. Most likely, your friends and family members will remember more from groups 1 and 5 than from groups 2, 3, and 4, with group 3 the least recalled group. This exercise demonstrates the serial-position curve. Save the recollections for a demonstration in Chapter 7.

Summary

1. What have cognitive psychologists discovered regarding how we encode information for storing it in memory? Encoding of information in short-term memory appears to be largely, although not exclusively, acoustic in form. Information in short-term memory is susceptible to acoustic confusability—that is, errors based on sounds of words. But there is some visual and semantic encoding of information in short-term memory. Information in long-term memory appears to be encoded primarily in a semantic form. Thus, confusions tend to be in terms of meanings rather than in terms of the sounds of words. In addition, some evidence points to the existence of visual encoding, as well as of acoustic encoding, in long-term storage.

Transfer of information into long-term storage may be facilitated by several factors. One is rehearsal of the information, particularly if the information is elaborated meaningfully. A second is organization, such as categorization of the information. A third is the use of mnemonic devices. And a fourth is the use of external memory aids, such as writing lists or taking notes. In addi-
tion, people tend to remember better when knowledge is acquired through distributed practice across various study sessions, rather than through massed practice. However, the distribution of time during any given study session does not seem to affect transfer into long-term memory. The effects of distributed practice may be due to a hippocampal-based mechanism that results in rapid encoding of new information to be integrated with existing memory systems over time, perhaps during sleep.

2. What affects our ability to retrieve information from memory? Studying retrieval from long-term memory is difficult due to problems of differentiating retrieval from other memory processes. It also is difficult to differentiate accessibility from availability. Retrieval of information from short-term memory appears to be in the form of serial exhaustive processing. This implies that a person always sequentially checks all information on a list. Nevertheless, some data may be interpreted as allowing for the possibility of self-terminating serial processing and even of parallel processing.

3. How does what we know or what we learn affect what we remember? Two of the main theories of forgetting in short-term memory are decay theory and interference theory. Interference theory distinguishes between retroactive interference and proactive interference. Assessing the effects of decay, while ruling out both interference and rehearsal effects, is much harder. However, some evidence of distinctive decay effects has been found. Interference also seems to influence long-term memory, at least during the period of consolidation. This period may continue for several years after the initial memorable experience. Memory appears to be not only reconstructive—a reproduction of what was learned, based on recalled data and on inferences from only those data. It also is constructive—influenced by attitudes, subsequently acquired information, and schemas based on past knowledge. As shown by the effects of existing schemas on the construction of memory, schemas affect memory processes. So do other internal contextual factors, such as emotional intensity of a memorable experience, mood, and even state of consciousness. In addition, environmental context cues during encoding seem to affect later retrieval. Encoding specificity refers to the fact that what is recalled depends largely on what is encoded. How information is encoded at the time of learning will greatly affect how it is later recalled.

One of the most effective means of enhancing recall is for the individual to generate meaningful cues for subsequent retrieval.

4. How does memory develop with age? Memory generally improves with age up through adulthood and then declines in later life. The causes are many, but increased metacognitive skills seem to be essential for memory development to occur. Older children develop more advanced theories of mind. Children with autism may lack such theories.

Thinking about Thinking: Factual, Analytical, Creative, and Practical Questions

1. In what forms do we encode information for brief memory storage versus long-term memory storage?

2. What is the evidence for encoding specificity? Cite at least three sources of supporting evidence.

3. What is the main difference between two of the proposed mechanisms by which we forget information?

4. Compare and contrast some of the views regarding flashbulb memory.

5. Suppose that you are an attorney defending a client who is being prosecuted solely on the basis of eyewitness testimony. How could you demonstrate to members of the jury the frailty of eyewitness testimony?
6. Use the chapter-opening example from Bransford and Johnson as an illustration to make up a description of a common procedure without labeling the procedure. Try having someone read your description and then recall the procedure.

7. Make a list of 10 or more unrelated items you need to memorize. Choose one of the mnemonic devices mentioned in this chapter, and describe how you would apply the device to memorizing the list of items. Be specific.

8. What are three things you have learned about memory that can help you to learn new information so that you can effectively recall the information over the long term?

Key Terms

accessibility
autobiographical memory
availability
consolidation
constructive
decay
decay theory
distributed practice
encoding
encoding specificity
flashbulb memory
interference
interference theory
massed practice
metacognition
metamemory
mnemonic devices
primacy effect
proactive interference
recency effect
reconstructive
rehearsal
retrieval (memory)
retroactive interference
storage (memory)

To learn more, examine the following experiments:

Brown-Peterson
False Memory
Serial Position
Sternberg Research

Von Restorff Effect
Encoding Specificity
Forgot It All Along
Remember/Know

Annotated Suggested Readings

Dewhurst, S. A., Pursglove, R. C., & Lewis, C. (2007). Story contexts increase susceptibility to the DRM illusion in 5-year-olds. Developmental Science, 10(3), 374–378. The use of the DRM in children is explored in this study. Many studies have explored ways to decrease the false-memory effect. This study exemplifies a way to increase the false-memory effect.


A study examining flashbulb memory for September 11, 2001. Differences between personal and global memory are explored.