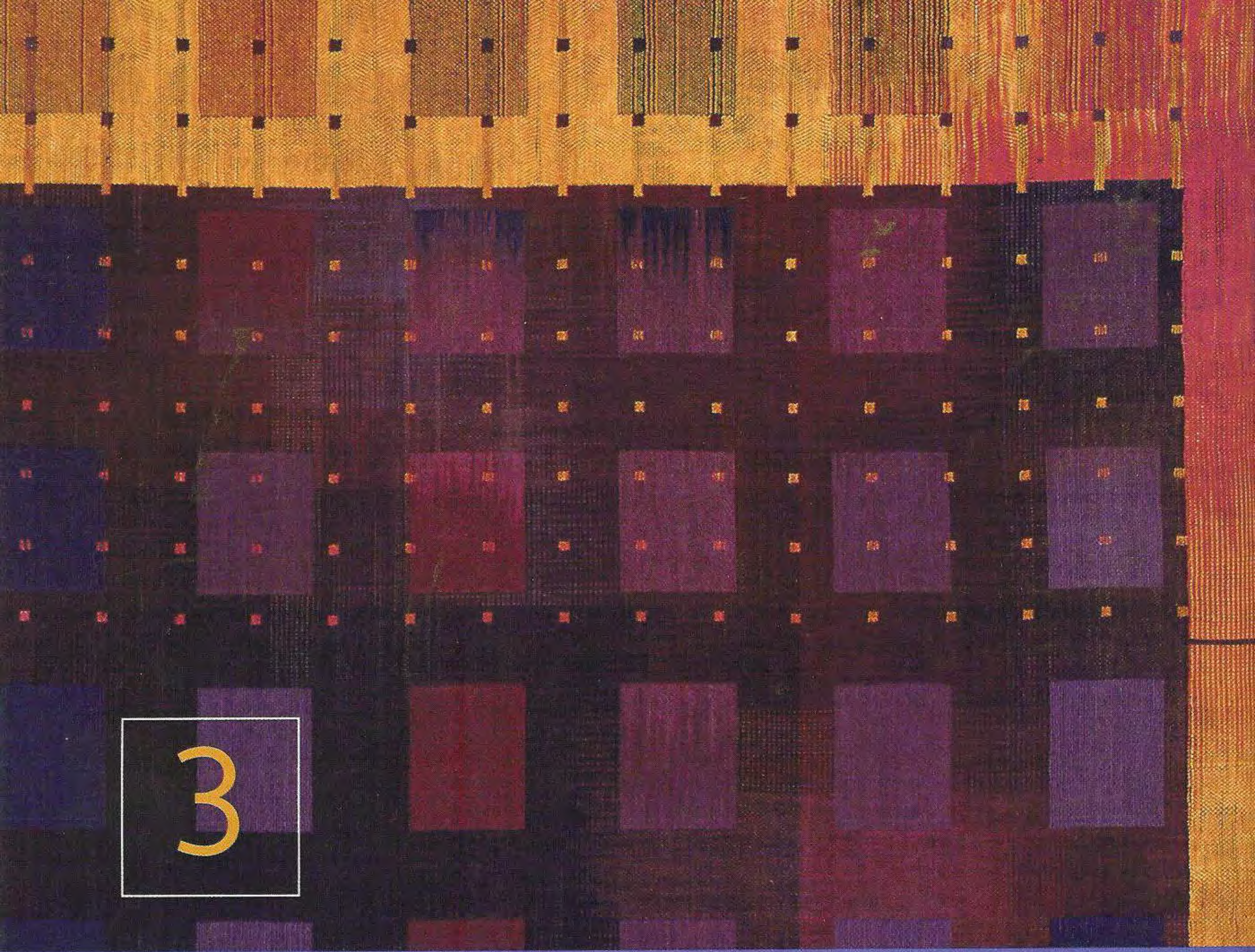
COGNITION
THEORY AND PRACTICE

Russell Revlin
University of California–Santa Barbara

WORTH PUBLISHERS



3

Attention

CHAPTER OUTLINE

"We consider ourselves as defective in memory, either because we remember less than we desire, or less than we suppose others to remember. . . . The true art of memory is the art of attention."

—Samuel Johnson

As soon as we wake up in the morning, we are immersed in a sea of stimulation and confusion: people asking questions, news on the TV, and pets (or children!) wanting food. At the same time, we are trying to juggle a variety of mental tasks. We may need to plan our day, remember where we put our keys, and decide what we want to eat for breakfast. This sensory input was described by one of the first American psychologists, William James (1842–1910) as a "blooming, buzzing confusion" (1890, p. 462) that starts at birth and never stops. Yet, most of us effortlessly focus on the important events of the moment and tune out irrelevant stimulation: the creak of the stairs, people we see getting on a bus, or the hum of fluorescent lights in a classroom. We notice some things and don't notice others. Meanwhile, other sorts of sights or sounds come in and out of focus, as when we register the tight fit of our shoes when we first put them on and then stop noticing their presence on our feet within a minute or two. At other times we seem to be able to focus on two things at once, such as driving a car while listening to the radio. Our attentional system allows us to achieve this broad array of mental feats.

What Is Attention?

Attention describes a set of cognitive processes that allow us to concentrate on one set of events in our environment while ignoring other events. Attention controls our mental environment by choosing the events that will enter our consciousness. When we are aware of the contents of our consciousness and react to them, we say we are paying attention. Not every event in our environment is allowed to pass through our attentional filter. For example, in the early part of the 20th century, the canneries in Monterey, California (made famous in the writings of John Steinbeck) used a unique series of whistles to alert their workers to the arrival of fishing boats in the early morning. Workers seemed to wake up to the distinctive tones of the whistle for their own cannery and sleep through the other whistles.

CHAPTER OUTLINE

Our attentional system, by deciding what we should focus on, also affects how we perceive the incoming stream of stimuli. For example, when our attention is directed toward a painting, we actually experience its colors differently from the colors and textures of objects on the periphery of our attention. We see color and other properties better when we are paying attention (Carrasco, Ling, & Read, 2004; Prinzmetal, Presti, & Posner, 1986; Talgar, Pelli, & Carrasco, 2004).

Properties of Attention

For all the wonders that our attention can accomplish for us, it seems also to constrain what we can be aware of and for how long we can focus on a single event. Over a century of research has shown that our attentional system is limited in how much it can take in and selective in what it offers us. Perhaps the most important fact is that attention is basic to everyone's cognitive system.

Attention Is Limited How long are you able to pay attention and stay on task? The answer probably depends on how interesting the task is and what kind of distracters you experience. During World War II, the British Navy was interested in how long it should keep people staring at radar screens or listening for beeps on sonar. These are important but incredibly tedious military tasks. To answer this question, Mackworth (1950) developed a task that bears his name (the Mackworth Clock), which was briefly described in Chapter 1. Mackworth had young recruits stare at a clock-like face with an arm (emulated in **FIGURE 3.1A** with a dot) and press a button when the clock arm moved in a jerking motion (skipping 2 seconds). He found that errors in missing the jerking motions (called targets) increased with the time spent staring at the clock. **FIGURE 3.1B** shows that by the end of the first 30 minutes, the observer missed 15% of the targets, and this error rate nearly

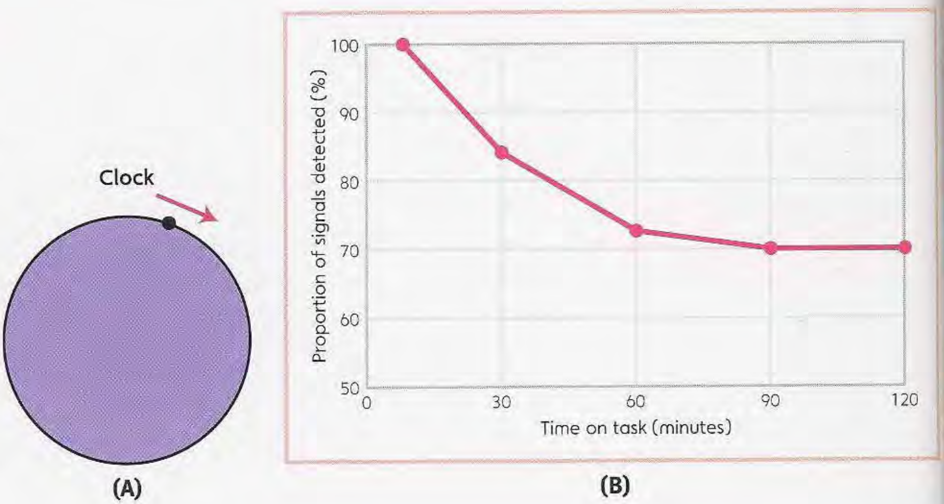


FIGURE 3.1 Mackworth Clock To determine whether attention diminishes over time, volunteers stared at a dot moving around a clock-like face (A). The observers had to be vigilant and announce when the dot skipped a stop. The graph (B) shows that the longer the observers performed the task, the more misses they made.

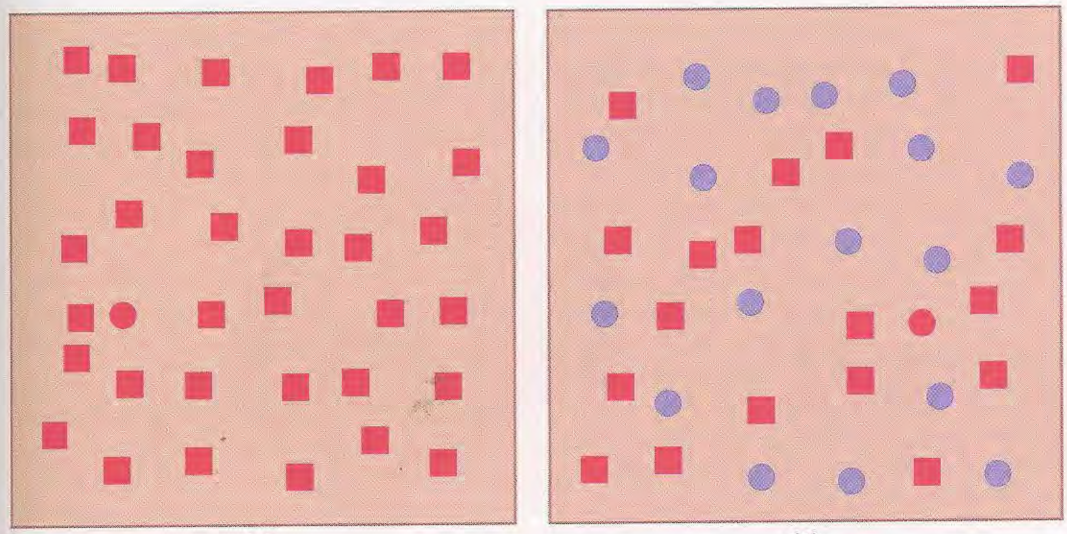
Source: Based on Wellbrink & Buss (2004) doubled in the next 30 minutes. Performance on the task is even worse when the temperature of the room is above 84°F (e.g., Matthews, Davies, Westerman, & Stammers, 2000; Wellbrink & Buss, 2004; Wickens, 1992). Mackworth also performed studies in which participants listened for tones or beeps over headsets and recorded similar results. Human attention is a limited capacity system: It is able to focus on a limited number of activities for a fixed period of time.

Attention Is Selective Focusing on something—attending to it—is only half the story. In order to sustain our attention to one event in everyday life, we must filter out other events: We must be *selective* in our attention by focusing on some events to the detriment of others. This is because attention is like a resource that needs to be distributed to those events that are important (e.g.,Wickens, 1992). William James (1890) put it this way:

> Everyone knows what attention is. It is the taking possession by the mind, in clear and vivid form, of one out of what seem several simultaneously possible trains of thought. . . . It implies withdrawal from some things in order to deal effectively with others." (pp. 403–404)

This ability to home in on a relevant event to the exclusion of all else can occur so rapidly that the perceiver may be momentarily unaware of all the stimuli that have been excluded. This is sometimes referred to as **preattentive processing** (or **preattentive analysis**; Treisman & Gelade, 1980; Treisman & Gormican, 1988; Zhaoping & Dayan, 2006) and reflects the role of the mind's automatic reaction to events. You can experience preattentive processing by looking at **FIGURE 3.2A** and searching for the round object. If you are like most observers, you did not look at each object in the figure one at a time to find the circle, it just popped out. Even though the circle is the same color as the other objects, it has a unique feature: its shape.

FIGURE 3.2 Preattentive Processing When searching for a red circle among red squares, as in (A), the circle "pops out" because it is unique and requires only effortless, preattentive processing that examines all features at once. In contrast, when a target shares features with other objects in a display, as when looking for a red circle among other things that are either red or circular (B), the task requires focused attention—features are assessed sequentially and with effort.



(A) (B)

A newborn turns toward a stimulus, displaying the orienting reflex.

Blend Images/Alamy

Preattentive processing is activated by the unique item and not activated by any of the other ones. In contrast, look for a red circular object in **FIGURE 3.2B**. Did it pop out to you? Probably not. That is because the target object shares features with other objects in the display. In this case, you had to use your attention more deliberately in order to look at each object because preattentive processes could not be effective. This is called **focused attentional processing**.

Attention Is Part of Everyone's Cognitive Architecture

Attention is a universal component of the human cognitive architecture. It is part of our basic biology to react to any distinctive change in the environment and turn our attention to it. These **orienting reflexes** ensure that we pay attention to important stimuli and changes in our environment. One example of this is the rooting reflex. If you touch the cheek of a newborn infant, she will turn in the direction of the touch and open her lips (presumably to nurse). Similarly, a newborn infant will turn her head in the direction of a loud sound in the first days of life (Morrongiello & Clifton, 1984). A loud noise or a sudden movement by a pregnant woman can elicit an immediate startle reaction from her fetus by age 9 weeks (DiPietro, Hodgson, Costigan, Hilton, & Johnson, 1996). There is also some evidence of orienting toward sound in near-term fetuses (Lecanuet, Granier-Deferre, & Jacquet, 1992). In everyday life, such orienting reflexes can have a positive benefit. When our attention is captured by a sound, it also helps our visual system attend to what is in the direction of the sound (McDonald, Teder-Sälejärvi, Di Russo, & Hillyard, 2003).

Directing our attention toward an unexpected stimulus helps us to identify it (Loftus & Mackworth, 1978). When novel stimuli are presented to people of all ages, there is an increase in activity in a part of the brain referred to as the **where/what circuits** (see **FIGURE 3.3**). These two circuits process information about the spatial location of objects and allow us to name them. The where circuit runs from the visual cortex to the parietal lobe in the case of visual stimuli and from the auditory cortex to the parietal lobe in the case of sound (Pavani,

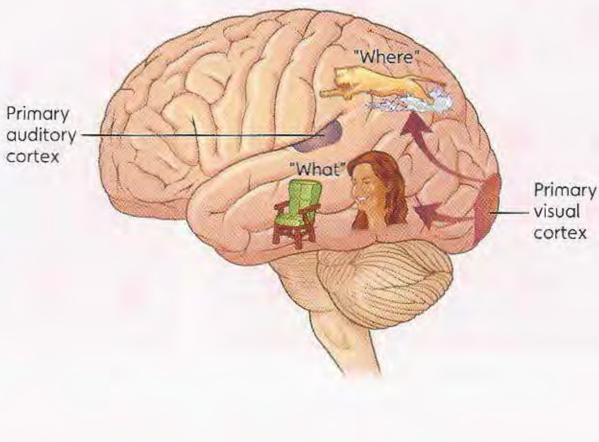


FIGURE 3.3 Where/What Circuits for Visual and Auditory Stimuli When people sense novel stimuli, there is an increase in activity in two circuits of the brain, called the where and what circuits, shown to the right for both visual and auditory stimuli. One circuit processes information about the spatial location of objects and the other activates areas of the brain that allow us to recognize and name them.

Ladavas, & Driver, 2002; Pinek & Brouchon, 1992; Rauscheker, 2011). The what circuit runs from the visual or auditory cortex to the temporal lobe. This circuit allows memories to be activated in order to recognize the object.

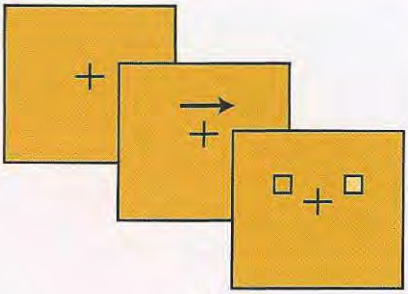
It makes sense that we would turn toward novelty. This reflex has survival value, whether we need to be alert to a jaguar in the jungle or the sound of tires screeching around the corner. Interestingly, when a stimulus is no longer novel, we don't orient toward it because it does not capture our attention. This is called **habituation** and accounts for how we get used to the tight shoes mentioned at the beginning of the chapter or the traffic noise outside our window. The strange sounds of a new house may initially make you nervous and disturb your sleep, but after a few days you will rarely notice them. When students attend a class for the first time, the sounds and slides in the lecture are novel. However, after a few class meetings, students habituate to the environment and may have to struggle to stay alert and attentive. College professors often try to maintain the attention of their students by creating interesting images and pacing the lecture with new topics (for a review of habituation across the animal kingdom, see Dethier, 1987).

The Spotlight: A Metaphor for Attention

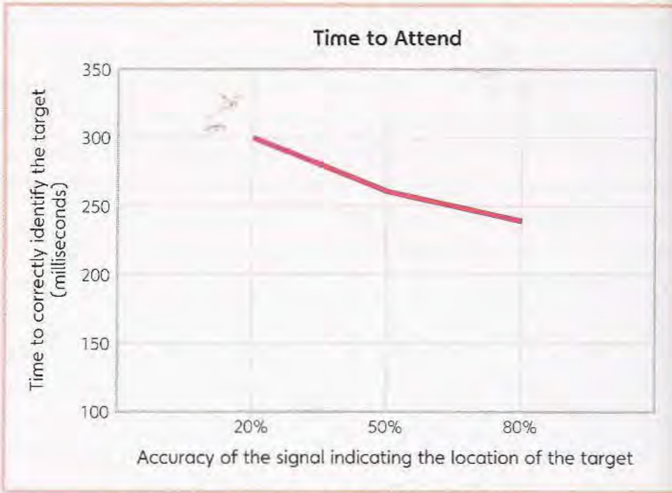
Imagine you are walking in the woods on a moonless night with a powerful flashlight. You shine the flashlight in the direction of a startling sound and a pool of light—a spotlight—illuminates a creaky old tree. The center of the pool of light is strong and clear and you can see the bark of the tree and the outline of a branch in detail; as your eye moves away from the center to the edge of the spotlight, the light is dimmer (called the *spill light*) and what you see is less easy to identify. Suddenly, your eye catches a movement at the edge of the light, so you shift the spotlight in order to identify the source of the movement. It's only a cat—you have just enough time to identify it before it runs out of the pool of light into the darkness.

This spotlight example conveys some important ideas about how attention works. Most people have a sense that while they are attending to one event (such as a conversation), there are other events (such as an unfamiliar person walking by) at the periphery of their attention. They often can't quite focus on this person unless they shift attention from the current activity to the peripheral one. These intuitions are supported by research, which suggests that we have something like an **attentional spotlight**, a cognitive ability to focus in or sharpen our attention, just as we do when we move the beam of a flashlight or focus a zoom lens (Broadbent, 1982; Castiello & Umiltà, 1990; Cave & Bichot, 1999; C. W. Eriksen & Yeh, 1985; Jonides, 1983; LaBerge, 1983; Podgorny & Shepard, 1983; Posner, 1980). Of course the spotlight metaphor refers to internal mental processing; we are not talking about moving our eyes to focus on something else, only moving our attention.

The spotlight metaphor provides a useful way to talk about basic elements of attention (Fernandez-Duque & Johnson, 1999): (a) attention can be moved and refocused like a spotlight; (b) it takes time to shift attention from one thing



(A)



(B)

FIGURE 3.4 Attention Task
(A) Participants stared at a plus sign in the center of a screen and pressed a button when they detected the presence of a bright square on the periphery that they could see *without moving their eyes*. An arrow indicated with varying accuracy where the target would appear (left or right).
(B) Participants' speed varied with the accuracy of the arrow—fast for high accuracy, slow for low accuracy. These results are not surprising until you remember that the participants' eyes did not move: only their attentional spotlight moved.

Source: Based on Posner, Snyder & Davidson (1980)

to another, just as it takes time to shift the focus of a spotlight; and (c) attention has a limited range, just as the light in a spotlight is dimmer at its periphery. Although the term *spotlight* suggests that it refers only to visual attention, the spotlight could also refer to an auditory experience such as listening to someone speaking to you and not attending to other nearby conversations.

An illustration of how the spotlight works can be seen in a classic study by Posner, Snyder, and Davidson (1980). In it, participants were asked to stare at a plus sign in the center of a screen and press a button when they detected the presence of a bright square on the periphery that they could see without moving their eyes. The display is shown in **FIGURE 3.4A**.

During each trial, the participants could see an arrow that would be displayed to indicate with 80% accuracy where the target would appear (left or right). On some trials, a double arrow would appear that pointed in both directions and was clearly uninformative. The results are what you would expect: Participants' attention followed the directional arrow. They were faster and more accurate when the cue was correct (80% of the time) than when it was incorrect (20% of the time). Their accuracy and speed were intermediate on the uninformative condition (50% of the time). These results are not surprising until you remember that the participants' eyes did not move. They stayed fixed on the central plus sign. The movement that occurred was internal, within their attentional system. This shows that people can shine their attentional spotlight on their mental representation of a display just as they can flash a spotlight on an external display.

Because it is commonplace for people to have to shift their attentional spotlight, cognitive psychologists have wondered how long this might take. The answer can be seen in the experiment by Posner et al. (1980). Participants were obliged to move their attentional spotlight when they shifted their attention from an incorrect location to a correct one. The time to shift attention can be computed by comparing the time taken to make the judgment when the arrow is correct

(240 msec) with the time to make the judgment when the arrow points incorrectly (300 msec). The latter situation requires the observer to shift attention from the wrong spot to the correct one. The graph in **FIGURE 3.4B** shows that people take about an additional 60 msec (0.06 sec) to move their spotlight when the prompt is incorrect. We often don't notice events that occur this rapidly; for example, people often claim they can read the newspaper and listen to a conversation at the same time. In fact, their attentional spotlight is simply switching back and forth so rapidly that it seems as if they are processing two events at once.

The spotlight metaphor tells us that a person's attention has a limit or boundary. The *flanker task* has been developed to estimate the extent of this attentional boundary (A. Cohen & Shoup, 1997; B. A. Eriksen & C. W. Eriksen, 1974). Participants are asked to look at a string of five letters and to focus on the central letter (see below). The participant pushes a lever to the right if the center letter is either an *H* or a *K*, and pushes the lever to the left if the center letter is an *S*.

(a) K K H K K [lever right]
(b) S S H S S [lever right]
(c) H H S H H [lever left]

If the attentional spotlight is very narrow—say, the size of a single letter—then the observer should not be aware of the letters to the right and left of the center *H*. In this case, the ability to identify the *H* should not be influenced by what letters are on the periphery. The speed and accuracy in all three conditions ought to be the same: Press the lever to the right for (a) and (b), left for (c). However, if the attentional spotlight is wider than a single letter, the participants may be aware of the letters on the edges of attention and may confuse those letters with the center *H*. If the *K* on the periphery enters consciousness, the participants may think that *K* is the center letter, but they will still press the lever to the right in (a) because the rule is "press for either an *H* or a *K*." However, if the letter on the periphery is an *S* and it is unconsciously perceived, the participants may get confused and press the lever to the left in (b), responding as if the center letter were an *S*. Or, the participant may get confused in (c), thinking that the center letter is an H.

As it turns out, this is what happens. People are faster and more accurate at identifying the *H* in the first string than in the second string (b) and equally confused by the peripheral letter in (c). The findings show that the letters on the periphery, called the *flankers*, are analyzed by the attentional system even though the observers are directed to look only at the center letter. This effect of the flanking letters occurs only if they are within 1° from the center target. How wide is this attentional boundary? At arm's length, the nail of your index finger (the one next to the thumb) casts an image of 1° on your retina. Therefore, in terms of attention to the visual world, we are able to attend immediately to anything that casts an image of 1° or less from the center of our attention (Posner, 1980; see also Intriligator & Cavanaugh, 2001).

Is there a limit to how many items we can attend to within the 1° spotlight? Put another way, how much can we attend to at once without incredible effort? Philosophers refer to this as our **span of apprehension**. Before you read about how we measure this span, try the task in Demonstration 3.1.

DEMONSTRATION 3.1

Subitizing

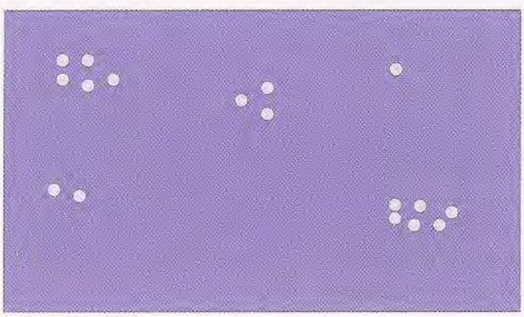
Select seven or eight coins, all of the same size, and place them in a bag. Now, reach into the bag and grab a handful of coins (without looking at how many are in your hand) and place them on a table so that they fall near each other. Your job is to say how many you see as quickly as you can. Do this repeatedly for different numbers of coins. People typically require more time to make their judgment as the number of objects in a collection increases. In one of the earliest studies of this task, philosopher William Hamilton (1859, p. 177) noted that

> If you throw a handful of marbles on the floor, you will find it difficult to view at once more than six, or seven at most without confusion; but if you group them into twos or threes, or fives, you can comprehend as many groups as you can units.

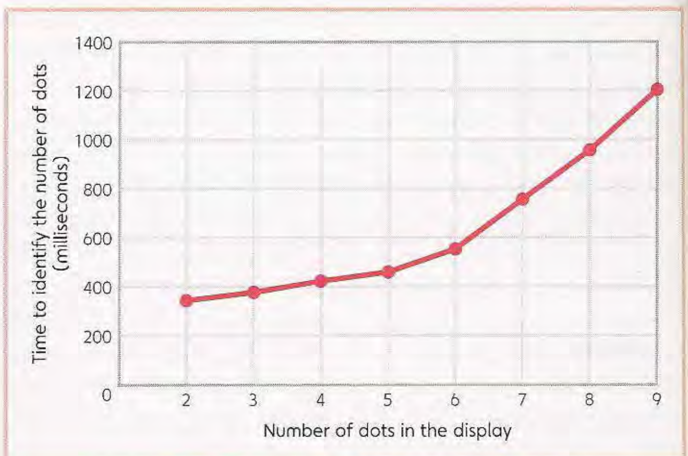
The task you just performed is called **subitizing**: "the rapid labeling of small quantities of simultaneously presented items" (Kaufman, Lord, Reese, & Volkmann, 1949, p. 520). A typical display for subitizing is shown in **FIGURE 3.5A**. Research findings from this kind of task show that a maximum of four objects appears to fit into the basic attentional spotlight. We know this because when people are timed in estimating the number of dots on a screen, there is a break in the curve. **FIGURE 3.5B** shows that for one to four items, each additional item requires an extra 40 to 80 msec to estimate. However, from six to nine items, people require about 200 msec per additional item to estimate. This has led to the conclusion that we are able to automatically estimate four or fewer items but have to physically count objects in larger amounts (e.g., Gallistel & Gelman, 1992; Trick & Pylyshyn, 1994).

In a subitizing task such as the one in Demonstration 3.1, students often report that the pattern made by two coins is experienced by them as a line, three coins as a triangle, and four coins as a quadrilateral (Mandler & Shebo, 1982). However, in spite of people's personal impressions, PET studies of the brain (see Chapter 2)

FIGURE 3.5 Subitizing How many things can a person count in a single glance? (Consider the groupings of dots in [A].) Research on subitizing shows that we can nearly instantly identify up to 4 dots at a time (B). Groupings of more than 5 dots require effortful processing that needs about 200 msec for every additional item.



(A)



(B)

have found that the same brain areas are involved whether you are looking at four objects or nine. But what actually changes is the amount of brain activation: As the number of items increases, the activation in the visual cortex also increases (Piazza, Mechelli, Butterworth, & Price, 2002; see also Balakrishnan & Ashby, 1991, 1992). This research on subitizing helps identify the boundaries to the attentional spotlight and shows that the concept of the boundary has a biological basis.

SECTION SUMMARY

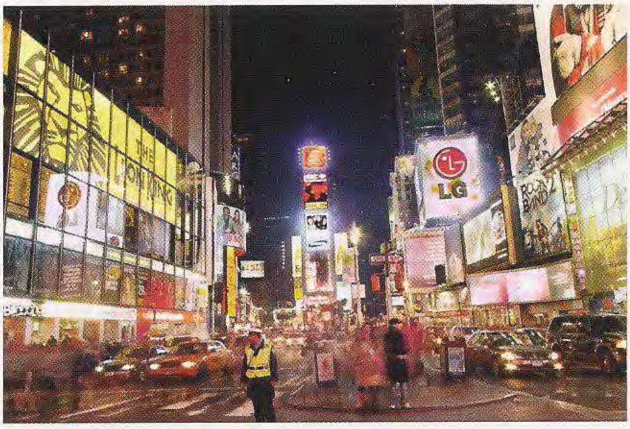
What Is Attention?

Attention is a critical element of the human cognitive architecture. The human attentional system consists of a set of cognitive processes that permits people to mentally focus on some items or events in their environment and to filter out others. Attention is limited in terms of how many events it can focus on and how long it can maintain its focus. It is also selective, but its action can occur so rapidly that it is completely inaccessible to conscious awareness, in which case we refer to it as preattentive processing. All humans, from the moment of birth (and possibly before), possess an orienting reflex that allows them to orient toward novelty and other potentially important events through the attentional system.

The attentional spotlight is a useful metaphor for how we are able to pay attention. Cognitive research has shown that just as with a spotlight, attention can be moved and refocused on relevant objects and topics, and it takes time to shift our attention from one to another. Human attention has a boundary of about 1° in the visual system: The strength of our attention diminishes outside our central area of focus, just as the light in a spotlight is dimmer at its periphery. Within the spotlight we are able to immediately grasp the number of objects we are observing, up to about four items. After this quantity we can make judgments of numbers only by actually counting the objects.

The Platform for Attention: Sensory Storage

Although common sense suggests that we cannot pay attention to more than one thing at a time, we are in fact bombarded on a regular basis by information flowing to us along many dimensions at once. It takes time and cognitive effort to identify the events that we face, to decide what to react to first, and to focus on the relevant stimuli. Fortunately, nature has provided us with a memory system called **sensory storage**, which acts as a buffer memory system to host the incoming stream of information long enough for us to pay attention to it. Sensory storage is called a *buffer memory* because it separates the incoming stimuli from everything



Times Square in New York at night bombards the individual with sensory stimulation: lights, noise, people, vehicles, movement.

Alexandre Fagundes De Fagundes/ Dreamstime.com else going on in our cognitive system. Sensory storage performs a similar kind of insulating function with incoming information.

The nearly unlimited stream of sensory events comes at us so rapidly that we need a way of holding back the tidal wave of information long enough to comprehend what we are experiencing. We need to buffer the environment around us. Cognitive psychologists refer to sensory storage by different names, including **sensory memory** and **sensory information storage (SIS)**. By whatever name it is called, sensory storage is a hidden memory system because we are rarely conscious of its actions in everyday life.

Sensory storage has separate buffer memories for each type of sensory input: sight, sound, touch, smell, and so on. The need for such buffers is easy to illustrate. Suppose someone asks you a question and you miss a key word because you were not processing the individual words quickly. You reflexively say "What?" and the speaker begins to repeat the question; however, all of the words in the question have actually made it into the auditory buffer of sensory storage (called *echoic storage*). By the time the person has repeated the question, you have accessed your memory of the words, picked up the missing one, and perhaps have begun answering the speaker's question while she is still in the process of repeating it—much to her annoyance. Sensory storage is important to normal visual processing as well. When people read, the movements of their eyes, called **saccades**, are ballistic: They rapidly dart from point of fixation to point of fixation, at which time most information is gathered. During these rapid eye movements, we do not experience a blur or "smear" of the visual signal. This is because the visual processing shuts down (called *saccadic suppression*) during the movements (Burr, Morgan, & Morrone, 1999), but perception appears smooth and continuous because sensory memory provides a persistence of the images, which bridges the gap between the fixations. (More will be said on this in Chapter 10.) This is another way that sensory storage buffers our experience so that we can focus on just the important events.

The distinctive properties of sensory storage can be revealed in the answers to four questions. These same four questions will also be used to gain an understanding of the memory systems described in Chapters 4–8.

1. **Capacity**: How much information can the memory system hold?
2. **Duration**: How long is the information held?
3. **Forgetting**: Why do we forget information?
4. **Coding**: How do we retain the information?

The Capacity of Sensory Storage

Because sensory storage is invisible to our conscious, everyday activities, it requires clever tasks to investigate how it works. Cognitive research on sensory storage was given a boost by Sperling (1960). He displayed cards on which numbers and letters were written. The cards contained 2–12 items and were shown to the participants for only 50 msec (0.05 sec) by means of a machine called a *tachistoscope*. The 2-, 4-, and 12-item displays look something like the following (see **FIGURE 3.6**).

The displays were set at a distance so that the information would be presented to the center of the observer's eyes and at a speed that prevented any eye movements. At best, the observer would only be able to scan the mental display, not the physical one. The results are shown in **FIGURE 3.7**. You can see that participants were good at reporting back what they saw as long as the display had fewer than five items. However, as the number of items in the display exceeded five, participants were still only able to repeat back between four and five items. This would normally indicate that the capacity of sensory storage is only 4.5 items. However, participants claimed they saw more than they could report.

Sperling (1960) thought that the reason people could not report more than 4.5 items was that the information was leaving their memory faster than they could report it. By the time they were able to report about five items, the rest had disappeared from memory. To test this, he used a technique called the **partial report procedure,** which is discussed in the Focus on Methods box.

After using the partial report procedure, the estimates of what observers can see in a brief visual presentation are shown in Figure 3.7. As the number of items presented increases, so does the number of items that an observer can report with only a brief delay. This suggests that perhaps there is no limit to the actual capacity of sensory memory. The limiting factor is how quickly we can report what we have experienced.

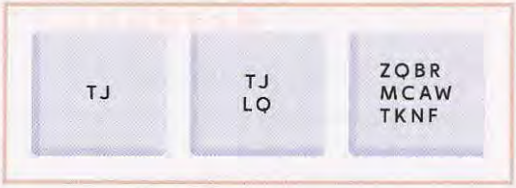


FIGURE 3.6 Three Different Stimuli for Tests of Span of Apprehension To see how many objects a person can grasp (apprehend) in sensory memory, practiced volunteers are shown displays of letters for about 50 msec. Here are different cards that have 2, 4, or 12 letters. The observers are supposed to verbally report the letters they saw. The results are shown in Figure 3.7.

Source: Sperling (1960)

Duration and Forgetting of Information in Sensory Storage

How rapidly is information lost from sensory storage and why? To examine this, Sperling (1960) waited different amounts of time to signal the observer to report the top, middle, or bottom lines. He found that by 300 msec (0.30 sec) after the

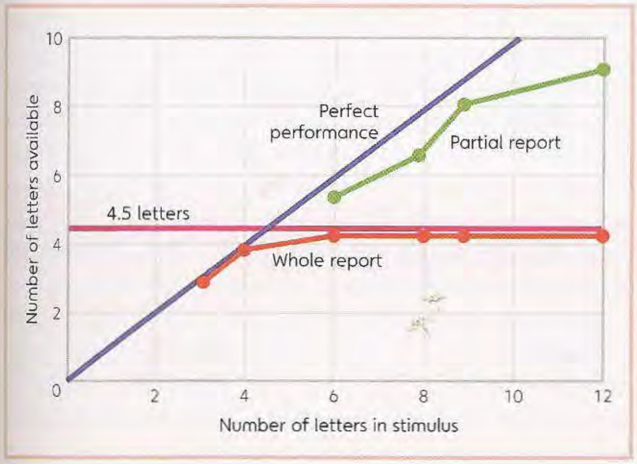
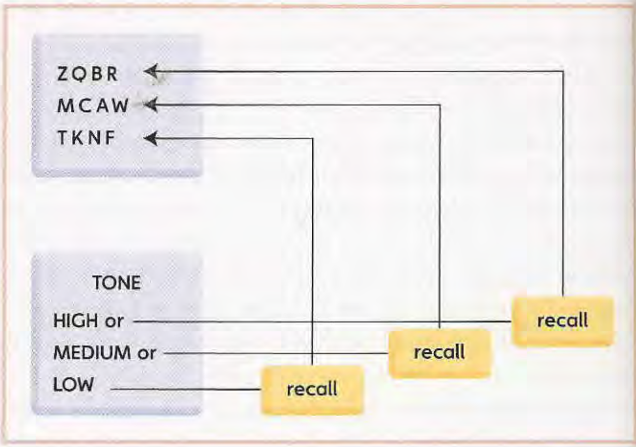


FIGURE 3.7 Span of Apprehension This is a graph of the number of letters a volunteer can accurately name after they are seen for 50 msec. The graph labeled "whole report" shows that people are accurate up to about 4.5 letters. This is the typical span of apprehension. However, using the partial report procedure (described in the text) shows that sensory memory holds much more information than we can report.

Source: Sperling (1960)

FOCUS ON METHODS

Span of Apprehension



It has long been known that people sense they have seen more events than they can recall (e.g., Gill & Dallenbach, 1926). The basic findings of sensory storage show that information disappears so quickly that it is difficult to estimate just how much people can apprehend. To get a sense of what people really see in a brief presentation, Sperling (1960) used what is now called the partial report procedure, in which he asked the participants to report back only selected parts of a display, not the entire set. For example, after Sperling presented the card with three rows of letters, the participants heard a high-, medium-, or low-pitched tone. These tones indicated whether the observer was to report back the top, middle, or bottom lines of the display. Because the display disappears before the tone is presented, the participant can only use the tone to scan the mental image of the card in sensory storage.

The principle of the procedure is similar to taking an exam. It is often not physically possible to be tested on each and every item that you learned in the course. It would take too long to take such an exam. Consequently, the instructor creates a test that samples from each of the possible topics. The student's score (a percentage of the exam) is extrapolated to represent a percentage of all the information he or she could have known. Sperling assumed that whatever percentage of a particular line students were able to recall reflected the percentage of all information that was available in memory.

So, for example, if a student reported 75% of a line (e.g., 3 out of 4 items on a line), this reflected the fact that the student possessed (however briefly) 75% of the total 12-item display (i.e., 9 of the 12 items).

letter cards were taken away, nearly half of the information in the buffer had disappeared from participants' memory. If the delay was 1 sec, the observers could not report any more information with the partial report procedure than they could with the whole report procedure (the standard "tell me everything you saw"). The results are summarized in **FIGURE 3.8**, which shows how rapidly information is lost from sensory storage.

Suppose there are two stimulus events: Event 1 and Event 2. Event 1 is presented to a person, is stored in the sensory buffer, and disappears in less than a second. If Event 2 occurs while Event 1 is still in the buffer, Event 2 can interfere with Event 1 and displace it from sensory storage. This phenomenon is called **masking** (Breitmeyer & Ganz, 1976; Breitmeyer, & Ogmen, 2000; Enns & Di Lollo, 2000; see also Holding, 1975) because one event masks or hides the other event from conscious awareness. The degree of masking reflects the time between the two events. If the two events are very close in time, about 80 msec or less, then to the observer they will appear to overlap and will be seen as a single event (Averbach & Coriell, 1961; Loftus, 1983). If the spacing of time is greater than 150 msec, the two events seem to clash and interfere with the identification of either one. With even longer spacing in time between the two events (say

FIGURE 3.8 Duration of Sensory Storage To determine the duration of information in sensory storage, participants perform a partial report memory task (described in Focus on Methods, p. 56) and are asked to wait different amounts of time before they hear a signal to report what they can recall. The graph shows that with a delay of 300 msec, sensory memory retains roughly 6 out of 12 letters. By the time one second (1,000 msec) has passed, sensory memory possesses about 4.5 letters—roughly the same as the whole report procedure illustrated in Figure 3.7.

350 msec), the first event will have already been processed and the second, potentially masking event, will be seen as distinct.

The findings from studies of masking allow an answer to the question of why there is forgetting from sensory storage. As we experience the stream of stimulation to our senses, one event hides or removes a previous event. If the spacing between them is great enough, our attentional system will capture them and they will be processed and more permanently stored. Otherwise, we are left with only a dim impression that we saw something but can't quite grasp what it was. We are immersed in a sea of stimulation that continuously plants and then removes information in sensory storage.

The Coding of Information in Sensory Storage

Sensory storage holds information in an unanalyzed way: The material held in this storage is close to its basic, sensory form. As a result, there are limits to what can be done with the information until it has been analyzed by later processing in long-term memory and short-term memory. **TABLE 3.1** presents a summary of the findings of many studies using the partial report procedure. The table displays what a person can be signaled to do with the information while it resides

TABLE 3.1

Results of the Partial Report Procedure and the Sensory Store

You can signal sensory storage to retrieve:	You cannot signal sensory storage to retrieve:
Letter size (small vs. large letters) Brightness (bright vs. dim) Location (top, middle, bottom row)	Categories (letters vs. numbers) (vowels vs. consonants)

in sensory storage (Chow, 1986, 1991; but see Coltheart, 1980; Loftus, 1983; Merikle, 1980; Mewhort & Butler, 1983).

In the original partial report procedure, students could be signaled to recall the top, middle, or bottom lines of a display. Table 3.1 shows that other basically sensory elements of a display can be signaled as well. But there are limits. This is because sensory storage is **precategorical storage**, which means that it stores information before it has been categorized. A person can access different sizes of letters, but cannot distinguish between letters and numbers. To do this requires access to long-term knowledge. Once information is categorized, it is no longer in the buffer but is processed by other memory systems, which are explored in later chapters in this text.

SECTION SUMMARY

The Platform for Attention: Sensory Storage

The incoming stream of events in our lives can occur so rapidly that they challenge the ability of our attentional system to focus its spotlight and evaluate the events. Fortunately, humans possess a buffer memory, called sensory storage, which hosts the elements of the incoming stream of events long enough for attention to identify and help categorize the events. The capacity of sensory storage is unlimited. The events are held for less than a second, either until the information fades away or is replaced by the next incoming event, called masking. The items kept in sensory storage are in a raw, unanalyzed, precategorical format. If the time in sensory storage is sufficient, attention will be able to focus on the event, which allows other memory systems to identify what we have just experienced.

Attention As a Filter of Sensory Input

Sensory storage is like a tray that holds events long enough for our attentional system to grasp the right items. Within the first second after an event is captured by sensory storage, it is processed by the attentional system, an activity called **attentional processing**. Unfortunately, the stimuli come so rapidly that the attentional system has to decide which packet of information to process first, because trying to process everything could result in an information bottleneck and attentional confusion. The attentional spotlight is sometimes directed to events in the environment depending on their physical characteristics, such as sound or brightness. Our attention may be automatically directed toward a police siren or a rainbow in the sky. The attentional spotlight can also be directed by the content of the event—its meaning or relevance for the observer. This could be the topic of a conversation, a person's name, or the announcement "All aboard." Of course, attention can also be directed by both the physical and the content characteristics of the stimuli, as occurs in the case of someone screaming "Help!"

Attending to Physical Features

Perhaps when you were young, you played outside your house after school. Amid the noise and sounds of your games, you could always hear your mother's or father's voice calling you inside. This was called the **cocktail-party phenomenon** by British psychologist E. C. Cherry (1953) because it is typical of a party situation where you are deep in conversation with someone in a loud and crowded room when suddenly your attention is "grabbed" by someone across the room uttering your name (Moray, 1959; Shapiro, Caldwell, & Sorensen, 1997; Wood & Cowan, 1995). Not only do you hear your name called even when you are not expecting it, but you can also detect the sound of a familiar voice (such as your parents') emerging from the noise of others. Sometimes our attentional system focuses on stimuli based on their physical characteristics (e.g., Broadbent, 1956, 1958). For example, Cherry noticed that aircraft controllers could have many voices speaking to them over the same speaker, yet they were able to associate pilot voices over their headsets with particular flights and were able to keep the messages straight to prevent an accident (Kantowitz & Sorkin, 1983). To be able to study this phenomenon in a laboratory, Cherry developed a *shadowing* task, illustrated in the Focus on Methods box.

When people are shadowing one channel, attention seems to filter out all but the most basic physical characteristics of the unattended channel, although

FOCUS ON METHODS

Dichotic Listening

E. C. Cherry (1953) was fascinated by our ability to attend selectively to one message or word amid many voices and messages. To study this, he developed a shadowing task (sometimes called a *dichotic listening task*). In it, the participant wears a special headset that presents a different message to each ear.

The participant is asked to repeat aloud (called *shadowing*) the message as it is being heard in a specified ear (called a *channel*). Typically, in these studies there are two messages, one on the channel that the participant is expected to attend to and another one on the channel that is supposed to be unattended. Typically, the listener only notices physical changes to the unattended message, such as when there is a change in the gender of the speaker or a change in volume. Using this procedure, researchers have found that while listeners attend to one input, they are unaware of the content of the message on the unattended channel. For example, listeners cannot detect that the language has changed or that the sentences on the unattended channel are nonsensical (e.g., Egan, Carterette, & Thwing, 1954; Wood & Cowan, 1995). Findings such as these led another British psychologist, Donald Broadbent (1956), to theorize that there was an attentional filter on the early processing of signals that prevents information from getting through.

some important items still get through, for example, the listener's name can be detected. This was shown in a shadowing task by Moray (1959), where a word on the unattended channel was repeated 35 times, yet most participants did not notice. However, a majority of them did hear their own names spoken on the unattended channel, just as in the cocktail-party phenomenon. It is not only people's names that can command our attention. If the message presented to the unattended ear contains sexually explicit words, then people notice them immediately (Nielsen & Sarason, 1981).

Attending to Content

It is clear from Moray's (1959) study and others (see Norman, 1968, 1976) that people can also distinguish signals based on their content. In one study (Treisman, 1960, 1964), students were asked to attend to a message in the right ear and ignore the message in the left ear. The message in the right ear was a coherent narrative taken from the novel *Lord Jim* (by Joseph Conrad). Without warning the listener in advance, the content of the message shifted from the right ear to the left after about 25 words. Even though the students were highly practiced at staying attended to one ear, they typically switched ears for a word or two in order to follow the message. Treisman (1964) asked: How did they know that the message had switched to the unattended ear if that message was unattended? The answer was unavoidable. The nonshadowed message had been given some attention, if only to process its basic semantic content. Humans are capable of focusing both on low-level features of messages as well as high-level, conceptual features. Put simply, continuously throughout the day, our attentional system is activated by both the sensory characteristics of the input and by what our memory system considers pertinent or important to our ongoing lives. This view of human attention is illustrated in **FIGURE 3.9** (see Deutsch & Deutsch, 1963; Norman, 1968, 1976).

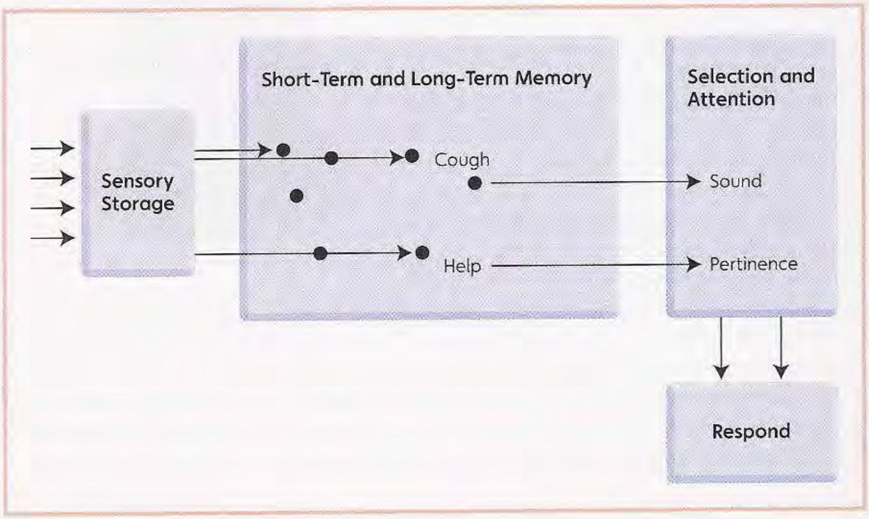


FIGURE 3.9 Model of an Attentional Filter After stimuli enter the sensory storage, they are captured by the overall attentional system, which includes long-term memory, short-term memory, and the pattern recognition process. Some physical features allow the stimuli to pass through an early attentional system for further processing. However, events that do not match the filter are not deleted (such as a cough); they are reduced or attenuated in intensity and are still available for processing somewhat later when our memory system identifies a physical event as having intrinsic importance (such as hearing our names). They are so pertinent to our lives that they too are followed when they are processed.

Source: Deutsch & Deutsch (1963)

The figure shows the flow of stimulation as it passes through sensory storage and how it commands our attention at different levels of processing. Sometimes our attention is captured by sensitivity to the physical features of the stimulus. If we are listening to a concert and someone starts to cough, the coughing can be momentarily distracting and command our attention. Because attention to physical properties of a stimulus comes early, we say that attention shows an **early-selection filter** (Broadbent, 1956, 1958). Another way to look at it is that the coughing doesn't completely eliminate our ability to process the music, it simply reduces or *attenuates* the attention to the music (Treisman, 1964).

Elementary loud sounds like coughing are not the only dimension that can interrupt our mental activity. Whispering can also command our attention because human speech may be relevant to us even though its volume would not suggest that it should pass through an early filter. Figure 3.9 makes this general point and also shows that some messages—no matter what their physical characteristics—are so important that they are permanently set to be relevant or pertinent (e.g., the sound of your name, the scream "Help!", the odor of mold, or even an angry face). These are examples of attentional processing called **late-selection filter** (e.g., Deutsch & Deutsch, 1963). Such stimuli are not necessarily related to your ongoing activities, but may be important to your life.

Attending to Relevance

The fact that both the physical characteristics and the content of what people experience help them to direct and focus their attentional spotlight implies that an enormous amount of processing is brought to bear in order to identify and react to the physical stimulus. It is as if our attentional system waits for all of the information to combine before it makes its decision to focus the spotlight. This understanding of attention has been called the **late-selection theory**. It presumes that even the supposedly unattended message actually enters our sensory storage and is only filtered out late in the process if it is not relevant.

An illustration of how the late-selection filter can affect what we experience is shown in a study by Corteen and Wood (1972). They presented a series of words to participants who received a mild electric shock to some of the words (they were not hurt by this procedure). Later, the participants shadowed words in one ear and occasionally a word in the nonshadowed ear would be one that was associated with electric shock. If the words in the nonshadowed ear were truly being filtered out of attention, then the participants should show no reaction when one of the shock-associated words was presented. However, the presence of these words elicited a *galvanic skin response* (GSR): a change in electrical conductance of the skin (similar to the response measured by a lie detector device). This indicates that these words were detected (unconsciously) even though the participants were supposed to filter them out. The researchers not only found a GSR to the previously shocked words, but also to words that were synonyms of the shocked words. This definitely shows that our attention can be recruited on the basis of meaning and that the early filtering of attention can be overruled by the late selection of pertinent events (e.g., MacKay, 1973).

SECTION SUMMARY

Attention As a Filter of Sensory Input

The human attentional system filters the information coming in through our senses that is momentarily stored in sensory storage. The attentional filter is normally set to "relevance" and allows those sights and sounds that are relevant to pass through a series of filters for our ongoing activity. Sometimes these filters are set to an early filter to attend to the physical aspects of events (e.g., a cough can capture our attention in a theater); sometimes it is captured by a late filter that detects events pertinent to our lives (e.g., the sound of our name heard across a noisy room). It also focuses its spotlight and allows people such as aircraft controllers to track the speech of many pilots at the same time, and sets our filters so that we are not disturbed by low-level events like the whir of a fan or the cough of another audience member while we are watching a film.

Automatic and Controlled Processes of Attention

Are we always in control of our attentional spotlight? Sometimes it seems that our attentional system is operating independently of any conscious control on our part. Imagine driving on a highway at 65 mph (95 feet per second), listening to music, and thinking about a scene from a movie you have just seen. How are you able to adjust to subtle changes in the speed of the cars in front of you or cars that are merging into your lane? Has it ever surprised you that you are able to take your eyes from the road to adjust the radio, yet you continue driving effortlessly? Some of these adjustments to the events around you are being handled automatically by your attentional system, which alerts you to danger. These are called **automatic processes** because they produce decisions that are not consciously controlled. You are not at the whim of these automatic processes; you can reign them in by conscious effort. For example, you can deliberately attend to the distance between your car and the one in front of you. This is called **controlled processing.**

Characteristics of Automatic Processing

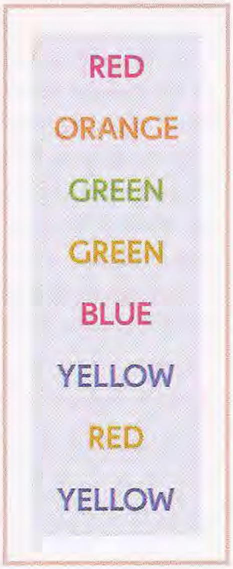
Automatic processes are evoked without making decisions or necessarily intending them to occur. They can be wired in, as are simple reflexes, or they can be a learned combination of reactions that repeatedly go together. The operation of automatic processing can be easily illustrated by a phenomenon called the **Stroop effect.** Observers are shown words printed in different colors. Their task is to name the color of the ink in which the color word (red, brown, etc.) is printed. To experience the effect for yourself, go to Demonstration 3.2 and do the exercise there before reading on.

DEMONSTRATION 3.2

The Stroop Effect

In the original Stroop (1935) Color–Word Interference Test, students were shown words that were printed in different colors. Their task was to name the color of the ink in which each word was printed. To get a sense of how the participants in the original study reacted to the task, look at the list of words to the right and name the color of the ink for each item on the list. Do this *as quickly as possible* and notice where you pause or stumble.

Which items did you have problems with? Were the first three words easy? These words and their ink color match. However, the next five words named a color that did not match their ink. Did you stumble over these words? Stroop's students took nearly 75% longer to identify the color of the ink when the ink was inconsistent with the color name, compared with the time required to name patches of the same color without the words.



The interference effect illustrated by the Stroop task occurs because of a conflict between the color's name and the name of the word (e.g., J. D. Cohen, Dunbar, & McClelland, 1990). Skilled readers cannot stop themselves from reading the word, even though it is not relevant to the task. Indeed, reading is so automatic that efforts to have people avoid reading the words have been unsuccessful (T. L. Brown, Joneleit, Robinson, & C. R. Brown, 2002). The memory code for the word is automatically activated while the student is trying to name the color. When the color word is different from the name of the color, the two names interfere with each other and processing is slowed and prone to error. However, when we ask students to read just the color words (and not name the color), there is no interference (Dunbar & MacLeod, 1984; see also Melara & Mounts, 1993).

Another characteristic of automaticity is that it occurs rapidly and does not require a lot of attentional resources for its operation (Posner, 1975). In the Stroop task, reading the words is an automatic process and it is not slowed down by having people identify the color of the ink, which is a more laborious task (T. L. Brown et al., 2002). Yet another characteristic of automatic processing is that how it occurs is generally impenetrable to conscious awareness (Posner & Snyder, 1975; Shiffrin & Schneider, 1977). You can test this yourself. Read the next two sentences and decide whether each is grammatical in English.

1. We wented to the store.
2. We heard the bird.

If you are a fluent speaker of English and more than 6 years old, you indicated that the first was ungrammatical and the second was grammatical. While you may be able to state a grammar rule that the first one violated, you probably can't explain precisely how you made the initial assessment. This is because you are so skilled in language that these kinds of judgments truly occur with little awareness or effort and command few attentional resources.

Automatic processing can get us into trouble. As we go about our daily lives, we sometimes react automatically to other people as if they were categories, rather than people. If we are accidentally jostled in a crowd, we may automatically register superficial characteristics of the other person, such as the color of the person's skin or gender, and associate rudeness with the person's characteristics (Wegner & Bargh, 1998). Because of this, automatic processing is said to be "mindless" because we are using categories in a way that are irrelevant to a current situation (Langer, 1975).

Characteristics of Controlled Processing

Controlled processes, in contrast with automatic ones, are often available to conscious understanding: You know when they are operating (Norman & Shallice, 2000). When you see flashing lights in the rearview mirror as you drive down the highway, your attention system alerts you to this important turn of events (automatic processing). As a result, you decide to pull over and prepare your speech to the police officer (controlled processing). In general, conscious processes are willful: either intentionally performed or deliberately not performed.

Controlled and automatic processes are different, but they are not absolute opposites of one another. You can think of them as either on a continuum or as overlapping. The act of breathing provides a useful analogy. Breathing occurs reflexively and unconsciously. However, you can deliberately stop breathing for a minute or two, as you do when you hold your breath underwater. Automatic and controlled attentional processes can interact seamlessly. Sometimes when you recognize a face, you have an automatic feeling of knowing the person, but the person's name does not come to mind immediately. Indeed, if you are like most people, about 20% of the time you will have difficulty remembering the name of a person that you recognize (Young, Hay, & Ellis, 1985) and you have to consciously search your memory to try to retrieve the name.

A skilled typist at work on a laptop computer, hands flying, typing quickly.

RTimages/Alamy

When you begin to perform a new task such as driving a car, learning another language, or snowboarding, you expend considerable conscious effort trying to make the correct response to a situation by selecting among a large number of possible responses. But as a result of vast amounts of practice, the nonrelevant responses drop away and the correct ones are reinforced. Novice typists, for example, focus on typing individual letters and often look at the keyboard to check their accuracy. Skilled typists, on the other hand, look at whole words on the paper and rarely need to refer to the keyboard because typing has become an automatic skill.

Typing is usually considered a **closed skill**, where the learner's intention is to be able to precisely duplicate the behavior under a variety of *predictable* circumstances (e.g., keyboards may vary in angle or elevation and the keys vary in size and touch). Closed skills like typing are automated and encapsulated as if they are independent units. In contrast, **open skills** are applied in *unpredictable* circumstances and the person must commit attentional resources to the environment to compensate for the variability they encounter. This might occur when speaking to people with unfamiliar regional accents, playing a piano that produces a different quality of sound than the musician is used to (e.g., Allard & Starkes, 1991), or snowboarding on radically different terrain from season to season. Open and closed skills make different demands on attentional reserves, and the same skill may be closed or open depending upon the way a person has mastered it. For example, if someone learning a second language treats acquisition of the language as a closed skill and memorizes vocabulary printed on 3×5 inch cards or studies lists of verbs grouped by conjugation rules, he or she is likely to develop a kind of skill that is appropriate to classroom question-and-answer exercises, but not appropriate to speaking under normal circumstances (Segalowitz, 1997, 2000).

Just because many of our responses to the environment are under our conscious control does not mean that we always make thoughtful decisions. People who learned to drive a car many years ago were taught to pump the brakes to prevent them from locking up when trying to stop on a slippery surface. Now that antilock brakes (ABS) are standard on most cars, the appropriate way to stop is to depress the brake pedal firmly and keep your foot there until the car stops (the braking system does the pumping electronically much faster than a person could). Unfortunately, a common occurrence for people unused to driving cars with ABS is that they pump the brakes, which interferes with the braking mechanism. In this example, "accidents that could be *prevented* in the past by our learned behavior can now be *caused* by the same behavior" (Langer & Moldoveanu, 2000, p. 3). This is an instance of **mindlessness**: Even though we are engaged in a controlled process, we fail to evaluate what we are doing when we exercise control (Langer, 1975). It is as if we perform activities mechanically or by rote, that is, we are not "paying attention."

Why Are There Two Types of Attentional Processes?

What is the benefit to people to have both controlled and automatic processes? One benefit is that while controlled processes have the advantage of permitting reflection and thoughtful adjustment to what is happening to us, they are demanding of our cognitive resources and need to recruit attentional capacity to perform their functions. This is one reason why we are unable to actively attend to many tasks at the same time. In contrast, automatic processes make minimal demands on our attentional resources (e.g., Kahneman, 1973; Posner, 1975) and allow us to respond more quickly to events than we can when using controlled processes. If we reacted to the world only through controlled processes, we could not walk and think at the same time. Thanks to the joint use of controlled and automatic processing, we are able to focus our attention on critical, demanding tasks that are not easily automated while handling a seemingly unlimited number of concurrent tasks that make minimal demands on our attentional resources (e.g., Anderson & Lebiere, 1998).

The Dangers of Automaticity

Without automatic processes, our attentional system would be sluggish and ineffective; however, with a reliance on its greater efficiency comes the possibility of inappropriate responses. In the world outside the laboratory, attentional failures can be devastating. On February 9, 2001, the commander of the U.S. submarine *Greeneville*, after following standard procedures, ordered the submarine to surface. Too late, the commander realized that he had surfaced with another ship, the Japanese fishing vessel *Ehime Maru*, directly overhead, causing the death of 9 students on board. According to the U.S. National Transportation Safety Board (2005), the *Greeneville* crew was behind schedule and operating under time pressure; they were rushed and distracted by the presence of 16 civilian observers on board. The crew relied on their automatic attentional processing skills to identify dangers and spent only 80 seconds scanning the horizon with the periscope rather than the usual 3 minutes of controlled attention.

Under the demands of the social situation, neither the captain nor the officer of the deck saw the fishing ship, though it must have appeared in the periscope. The sonar picked up the *Ehime Maru*, but the sonar operator did not see it because his attention (though not his eyes) was focused on finishing a 10- to 15-minute job in 6 minutes. This is a case where normal attentional processes were misdirected to another task (dealing with visitors). Clearly, we cannot always rely on our automatic processes to perform flawlessly, especially when those processes are interrupted by having to attend to another task. This is especially the case when a task demands controlled attentional processing.

One framework for understanding tragedies like the *Greeneville*'s sinking of the *Ehime Maru* is the generic error modeling system (GEMS; Reason, 1990). According to this theory, many accidents are a result of two types of situations: (a) when automatic processes are *not* interrupted and taken over by conscious processes when they should be; and (b) when there is an unusual or unpredicted interaction between automatic and conscious processes.

The first situation happens to most people every year. In the first week of January, people frequently put the wrong date on their checks or papers even though they consciously know the year has changed. The second type of situation occurs when our automatic processing is interrupted and we have to apply

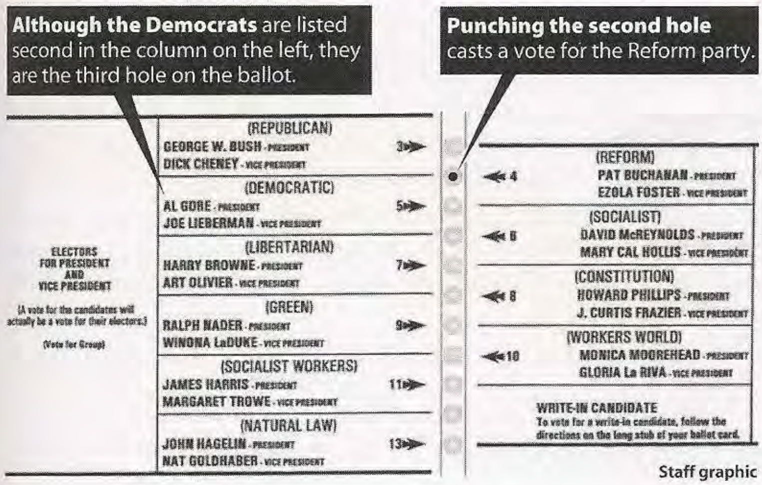


FIGURE 3.10 Florida Election Ballot The Florida ballot for the 2000 U.S. presidential election conflicted with normal attentional processes. The arrangement violated Gestalt principles, since the numbering of the holes did not correspond to the boxes for the candidates. The arrangement also violated typical left-right scanning: If the voter scanned left to right, from the name of the political party (in capital letters), the voter's gaze would land on the wrong hole. Ballots need to be congruent with voters' cognitive processes.

Sun-Sentinel Graphic

conscious attention in an unfamiliar way. A good example of this sort of violation of attentional processes occurred in the 2000 U.S. presidential election. The so-called butterfly ballot used in Palm Beach County, Florida, was an example of a design that promotes erroneous behavior because it is inconsistent with normal automatic processing. Inspection of **FIGURE 3.10** shows that the arrangement of the holes is incongruent with the arrangement of names. This in itself may have caused voters to misalign the names with the holes.

The role of automaticity in reading also comes into play here. English is read from left to right and reading quickly sets up an expectation that the holes corresponding to the names will be directly to the right of each name. They are not! You may think that the arrows will correct for the misalignment because they point to the correct hole. However, the arrows are not next to the names, so a reader would have to scan backward from the tip of the arrow in order to understand the name–arrow correspondence. For these reasons the construction of the butterfly ballot is not in keeping with normal cognitive processing and with the way our attentional system functions. According to newspaper reports at the time (e.g., "Presidential votes," 2000), nearly 10,000 votes were disqualified because voters punched more than one candidate for the same office and approximately 5,000 votes were punched for the wrong candidate. This ballot and its consequences would certainly justify the kind of human factors research described in Chapter 1.

SECTION SUMMARY

Automatic and Controlled Processes of Attention

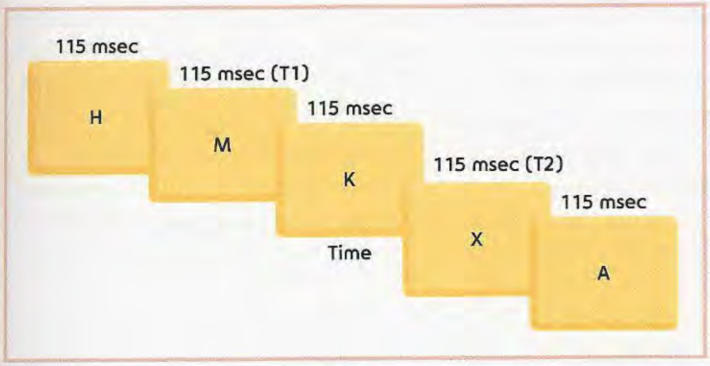
Human attention is a balanced system composed of two broad types of processing: automatic and controlled. Automatic processes are rapid and make minimal demands on our cognitive resources. They normally operate without conscious awareness of their functioning details. Controlled processing occurs when we consciously direct our attention and are aware of its deliberate functioning. Controlled processing is typically slower and requires more of our attentional resources than automatic processing. Both automatic and controlled processes complement each other. The fact that we possess automatic processes allows us to attend to tasks without overloading our attentional resources so that we can engage controlled attentional processes to respond to important events. In critical situations, however, we may unfortunately rely on automatic processes to function as they do in familiar situations when, in fact, controlled processes need to take over.

Attention Is a Resource

When people think of attention, they often imagine they only have some limited quantity of it to distribute. This reflects most people's sense that they are not able to pay attention to more than a few items or events at a time. The idea that attention is a resource distributed among tasks is embodied in the **capacity theory of attention** (Kahneman, 1973). It says that our ability to focus attention varies with the number and complexity of the tasks and how mentally energized we are at the time. The difficulty we encounter in performing simultaneous multiple tasks involves the resource *cost*: the amount of resources needed to perform the task. If the cost is too high, we are less than optimal in our performance. If this sounds a bit like a theory in economics, it's probably because its developer, Daniel Kahneman, received the Nobel Prize for his work in economics in 2002. The idea of resource limitation can be seen in four phenomena that challenge commonsense ideas about attention: attentional blink, repetition blindness, change blindness, and inattentional blindness.

Attentional Blink

Suppose that you point your flashlight at some important object and then, after looking at it, you turn off the flashlight. Although for a brief moment after you turn off the flashlight the level of ambient light bouncing off the walls or still being emitted from the bulb may be sufficient to see something, it quickly becomes dark. If a new object is presented for your consideration, it will take a moment for you to turn your flashlight back on and have the illumination increase sufficiently to attend to the new event. This period between the moment the light is too dim to see and the moment that you turn the flashlight back on to attend to something new is like quickly closing and then opening your eyes—a blink. In terms of attention, the **attentional blink** (a term coined by Raymond, Shapiro, & Arnell, 1992) is the moment when you are shifting your attentional focus and are unable to attend fully to a new target event. In terms of Kahneman's (1973) capacity theory of attention, there is a cost when we selectively attend to a visual event



(A)

(B)

FIGURE 3.11 Attentional Blink Paradigm Volunteers look at letters presented in rapid order (A). If they see either an M (Target 1) or an X (Target 2), they must press a button. If they press the button for the M, they sometimes miss pressing the button for the X if it occurs a few hundred milliseconds after the M. It is as if the attentional system "blinked." The graph (B) shows how accuracy is affected by the blink.

and this cost is a kind of functional blindness to other unattended events (Jolicoeur, 1999; Kanwisher, 1987; Mack & Rock, 1998; Simons & Levin, 1997).

Attentional blink has been studied in the laboratory using a method called *rapid serial visual presentation* (RSVP) shown in **FIGURE 3.11A** (Raymond, Shapiro & Arnell, 1992; Shapiro, Arnell, & Raymond, 1997). In it, many letters are presented one at a time on the screen. The observer is looking for two possible targets and presses a button when a target is seen. When the observer finds one of the targets, it is difficult to find the second one if it occurs soon after the first (Shapiro, Raymond, & Arnell, 1994). This is shown in **FIGURE 3.11B** (After Wagemans, Verhulst, & De Winter, 2003). The graph indicates that for a typical college student, the attentional blink is about a half second. That is, after a target is identified, the attentional system's resources are depleted and the observer will not be able to identify the next target for about a half second. The blink occurs for both auditory and visual events (Mondor, 1998).

Why would humans be plagued by such a limitation to the attentional system? We can only guess that an attentional blink is a way for the brain to ignore distractions so that it can focus its processing on the first target (Maki & Padmanabhan, 1994). If two events follow nearly simultaneously (e.g., less than 0.10 sec apart), then the brain grabs them as if the two were a single item and is able to process them both. When there is a substantial delay between the two events, the brain has to finish processing one item before it grabs the next; however, it will miss the second item if that item occurs at a critical time.

How does the attentional blink affect everyday cognition? Suppose you are driving along a freeway, paying attention to the distance between your car and the one in front of you, as well as to other cars around you. All of a sudden, you notice that a friend is driving a car in the lane next to you. You focus attention to make sure it's your friend. This impairs your ability to attend to the car in front of you for slightly less than a half second. This effect is smaller for younger adults (aged 17–30 years) than for older adults (aged 62–77 years; Lahar, Isaak, & McArthur, 2001; Widner, Otani, Adams, & Mueller, 1998). Interestingly, the amount of disruption (how long the blink lasts) depends on how physically close you are to your friend's car. If you glance left and your friend is right there in the car next to you, your blink is longer than if you see your friend a bit ahead and two lanes over (Kristjansson & Nakayama, 2002).

Repetition Blindness

Repetition blindness is defined as a decrease in the ability to perceive repeated stimuli during a rapid serial presentation of items. For example, if letters are flashed at you in rapid order and two consecutive letters are both *B*, then you may only remember having seen one *B*. This is not due to an inability to visually separate the letters, because the effect occurs even when the letters are in different cases (i.e., **B** and **b**) or are in different sizes (i.e., **B** and **B**; MacKay & Miller, 1994; Miller & MacKay, 1994). To experience this for yourself, do the exercise in Demonstration 3.3 before reading on.

DEMONSTRATION 3.3

Repetition Blindness

Try reading the following sentences aloud as fast as you possibly can. Do this by using a piece of paper and moving it across each sentence so that your eyes can't look back at a previous word. Try to take only a second or two to read each sentence.

1. Unless they are hot enough, hot dogs don't taste very good.
2. They wanted to play sports, but sports were not allowed.
3. They wanted to play sports today, but sports were not allowed.

If you are like most people, you slowed down at the second occurrence of a word or word fragment such as *hot* in *hot dog* in Sentence 1, or actually did not read the second instance of these words. This is repetition blindness. Because of repetition blindness, our visual system fails to record the second instance of *hot* as a unique event (Kanwisher, 1987; Kanwisher & Potter, 1990).

Like the attentional blink, the more items (or more syllables) between the two targets, the greater the accuracy in identifying the repeated word. For example, in Sentence 2 the lag between the repeated instances of the word *sport* is a single word (*but*); however, in Sentence 3 the lag is two words (*today* and *but*). The repetition blindness is less in Sentence 3 than in Sentence 2.

Cognitive psychologists study this phenomenon by rapidly presenting the individual words from a sentence to an observer. The observer's task is to press a button every time a target word is shown on the screen (Kanwisher, 1987). Many people are surprised when they read a sentence like the first one, because they fail to notice that *hot* is repeated (Kanwisher, 1987; Kanwisher & Potter, 1990). It is as if, when we perceive events, we need to create "objects" to be stored as "indicators" of what we have experienced (Kahneman & Treisman, 1984). We occasionally fail to do this when we don't treat the second repetition as a different object from the first. It is as if the two items compete for our attentional resource and our awareness of their existence and we can't tell whether there were two objects or one. We saw this phenomenon in the attentional blink studies. But here the "blink" is specific to a repeated word rather than just any word that is presented during a critical period (Morris, Still, & Caldwell-Harris, 2009). Similar to the findings regarding attentional blink, older adults show an increased rate of repetition blindness compared with younger adults (MacKay, Miller, & Schuster, 1994; see also Borovsky & Abrams, 2001).

Repetition blindness not only causes observers to miss words or letters, it can also cause observers to create illusory words. For example, if the words *lake*, *brake*, and *ush* are presented rapidly, one after another, for about 100 msec with a 15 to 30 msec break between the words, observers report seeing *lake* and *brush* and are astonished when told that *brush* was never presented (Morris & Harris, 1999).

Change Blindness

Change blindness is an everyday phenomenon that is somewhat similar to the attentional blink. Imagine you are looking at two photographs of Notre Dame Cathedral in Paris that are slightly different (see **FIGURE 3.12**). When you place the photographs side by side and compare them section by section, you can readily see the difference in just a few moments. However, if the pictures are flashed one after another repeatedly on a screen, each for about 250 msec with a gap of about 80 msec between pictures, you will find it difficult to discern any difference between the pictures (e.g., Grimes, 1996; Rensink, O'Regan, & Clark, 1997; Simons & Levin, 1997, 1998). This is especially true for changes that occur in parts of the scene that are not of central interest (notice how obscure the differences are in the pictures of Notre Dame in Figure 3.12).

(A) (B)

FIGURE 3.12 An Illustration of Change Blindness Notre Dame in Paris, as seen from Quai de Conti along the river Seine. Can you spot the differences between the two images? In the experiment, two pictures are flashed with a gap of about 80 msec. The difference between the pictures is subtle. The typical person requires many such flashes to spot the change. However, when they are side-by-side, the changes take only a few seconds to identify. The changes are easier to identify when they are central to the attentional spotlight.
J. Kevin O'Regan
Laboratoire de Psychologie Expérimentale, Centre National de Recherche Scientifique, Paris, France

Since these details are not what the pictures are about, observers tend to take a long time to notice the changes. Changes in objects included in the center of the attentional spotlight are detected earlier than changes in objects at the periphery of the spotlight (Rensink et al., 1997), although occasionally even changes at the center of the spotlight are not detected (Angelone, Levin, & Simons, 2003).

Change blindness can occur in situations outside the laboratory. In one study (Simons, 2000; Simons & Levin, 1998) the experimenter stops a person on campus and asks for directions holding a map. While the person is speaking to the experimenter, workers carrying a door pass between the experimenter and the person giving directions, blocking that person's view of the experimenter. During this brief interval, which lasts 1 or 2 seconds, the experimenter joins the workers by walking behind the door and an accomplice, dressed similarly, takes the place of the experimenter and begins talking to the unsuspecting person, who usually continues giving directions—apparently oblivious to the change in the person. When asked about their experience later, more than half of the participants had not noticed that they wound up giving directions to a different person. Those who noticed the change were primarily from the same age group as the experimenters.

Why are the participants blind to the change that has occurred? One answer has to do with the number of changes occurring in their immediate environment and the need to conserve attentional resources. The participant's attentional spotlight is focused on the task of giving directions—everything else is on the periphery of attention. Often the participant senses that a change has occurred, but is unable to identify automatically where it has occurred. As a result, he or she attributes change to the major event (the door) and not to the person to whom they were giving directions (Gegenfurtner & Sperling, 1993), as long as the two people who exchanged positions were from the same social categories (occupation, race, gender, etc.). In general, change blindness is greatest when the changed object is inanimate (furniture, boxes, etc.) rather than animate (people, dogs, etc.; New, Cosmides, & Tooby, 2007). This may be a result of the kind of environments in which humans evolved that linked survival to an ability to detect predators or prey—an ability all humans inherit (Rees, 2008).

Inattentional Blindness

The human attentional spotlight can sometimes cause observers to miss entire events—not just a letter or a word. This was demonstrated with college students who were asked to look at a video of two teams (one in white shirts, the other in black) rapidly passing a basketball around. One group of observers was instructed to count the number of passes by either the white- or black-shirted team. A second group was given a more difficult task and told to keep separate counts of bounce and aerial passes. These are attention-demanding tasks (Neisser, 1979). During one version of the video a woman carrying an umbrella walked through the scene. In another version a person in a full gorilla suit walked through. Less than half of the observers reported seeing the woman or the gorilla (Most et al., 2001; Simons & Chabris, 1999). The students performing the more difficult task reported seeing the gorilla less often than those in the easier task.

Low-level, automatic attentional processing might indicate to the observers that there was some object moving across the screen, but the ongoing demands of the controlled attentional processes took up the resources necessary to identify the moving object. Since observers rely on the automatic processes to identify the moving object, they may simply assume that the object is a basketball player rather than someone wearing a gorilla suit!

The research on **inattentional blindness** can help us understand one cause of traffic accidents. Any activity that consumes attentional resources, (i.e., controlled processing) will have an effect on performance on another attention-demanding task (Kahneman, 1973). Driving performance can be affected by memory tasks (Alm & Nilsson, 1995; Briem & Hedman, 1995), mental arithmetic tasks (McKnight & McKnight, 1993), and verbal reasoning tasks (I. D. Brown, Tickner, & Simmonds, 1969). This is also true of attention-demanding motor tasks, such as dialing a phone number or even the act of pressing a button to answer a phone call (e.g., Briem & Hedman, 1995; Brookhuis, De Vries, & De Waard, 1991). These findings are consistent with what we know about the effect on performance of controlled attentional processing, and they point to the potential disruption to driving that comes from talking on a cell phone.

Of the 137 million cell phone owners in the United States, 85% (120 million) use their phones while driving (Strayer, Drews, & Johnston, 2003). Studies using a simulated driving environment found that when students engaged in phone conversations about topics in which they were interested, they reacted more slowly to traffic signals and actually missed some of them altogether, compared with students not engaged in phone conversations (Strayer & Johnston, 2001). Strayer et al. (2003) found that students were more likely

Using a cell phone while driving affects your driving performance in a negative way, no matter what your age.

jabejon/iStockphoto

to be involved in traffic accidents when speaking on a cell phone when many cars were present than when just a few were present. The accidents tended to be rear-end collisions.

Using a hands-free phone does not appear to benefit attention over a handheld phone. Although a handheld phone may impair steering, it does not by itself affect controlled attentional processing. Both handheld and hands-free phones affect driving performance. Talking on a cell phone while driving has an equal overall affect on people of all ages: roughly 17% slower in reaction to highway conditions. However, when younger participants (20-year-olds) are talking on their cell phones, they are as slow as older participants (70-year-olds) who are not talking on their cell phones (Strayer & Drews, 2006, 2007).

Research shows that listening to a conversation, the radio, or books on tape does not impair driving performance (Briem & Hedman, 1995). While these are potentially demanding activities, you can momentarily disengage from them to focus on driving with only marginal impact. Engaging in a conversation with a passenger is not like conversing on a phone because a passenger can adjust the conversation depending on road conditions. Also, the driver can pause a conversation without appearing rude. In demanding situations when the driver is really distracted, a passenger can also warn the driver of danger.

SECTION SUMMARY

Attention Is a Resource

Our attentional processing is limited by the resource demands placed on it by external stimuli and requirements of the tasks in which we are engaged. Four examples of this limitation have been explored by cognitive psychologists: attentional blink, repetition blindness, change blindness, and inattentional blindness. These phenomena stem from the fact that our attentional resources require time to replenish themselves. We experience an attentional blink when we commit resources to identify one important event and it impedes our ability to identify the next important event because we have not recovered from the first attention-demanding event. The blink typically varies with the age of the observer. It is longer for older people than for younger people. Repetition blindness occurs when two important events occur within 100 msec of each other: They are caught in the same spotlight and treated as one event. Change blindness and inattentional blindness occur when our attentional spotlight focuses on a few critical elements in our environment. It frequently misses elements on the periphery of attention because of the need to alternate automatic and controlled processing. We tend to show less blindness for scenes that contain animals, which may reflect skills that our genetic ancestors needed for survival. Inattentional blindness has modern implications. The ability to attend to one event, such as the distance between your car and the one ahead, can be affected by the demands made on your attentional system by a cell phone call or seeing something important in the adjacent lanes of traffic.

The Neuropsychology of Attention

Slips of attention can happen to everyone. They can be as benign as failing to correct a spelling error or as dangerous as causing an automobile accident because you were answering your cell phone. Accidents are called accidents because they are unexpected and seem unavoidable. There are people, however, whose difficulties in paying attention are unfortunately not accidental, but are the consequences of neurological deficits. Four key disorders that affect attention are discussed in this section: simultanagnosia, hemispheric neglect, attention-deficit/hyperactivity disorder, and Parkinson's dementia.

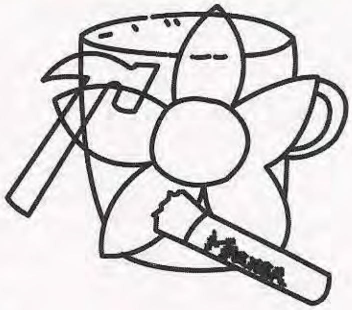


FIGURE 3.13 Stimulus Used to Test for Simultanagnosia People with Bálint's syndrome suffer from simultanagnosia. When they observe a scene with many objects, their attentional system can focus on only one of them; the rest of the scene is patchy. In this drawing, people with Bálint's syndrome can see only one of the objects.

Damasio, A. R. (1985a). Disorders of complex visual processing: Agnosia, achromatopsia, Balint's syndrome, and related difficulties of orientation and construction. In M. M. Mesulam (Ed.), Principles of Behavioral Neurology. Philadelphia, PA: Davis.

Simultanagnosia

Unfortunately, some people's attentional focus is so limited that they cannot see objects to the right or left of where they are attending. Their situation is called **simultanagnosia,** which refers to a difficulty in recognizing two or more objects at the same time (Farah, 1990; Michel & Henaff, 2004; Rizzo & Vecera, 2002). Clinical psychologists refer to simultanagnosia as Bálint's syndrome (Damasio, 1985a; Rizzo, 1993). When people who suffer from this condition observe a scene with many objects, they are not able to identify more than one of the objects unless their attention is deliberately guided to those objects. Notice the drawing in **FIGURE 3.13**. It is composed of the overlap of four objects. Do you see all four? People with Bálint's syndrome can see only one of them. They cannot move their gaze around the picture to identify the remaining objects. This is sometimes the result of stroke damage in the parietal lobe (Damasio, 1985a). Life with this syndrome can be difficult because sufferers frequently bump into objects that fail to activate their attentional system.

Losing Sides: Hemispheric Neglect

Neurologist Oliver Sacks (1985, p. 77) described the case of an older woman with attentional problems:

> Sometimes (when eating) she complains that her portions are too small, but this is because she eats only from the right half of the plate—it does not occur to her that it has a left half as well. Sometimes, she will put on lipstick and make up the right half of her face, leaving the left half completely neglected.

This malady is known as **hemispheric neglect** (or **hemineglect**); it occurs when people are unable to focus their attention on a portion of their visual field. It is as if they are blind to one half of what they should be able to see. However, their vision is completely intact (Mesulam, 1998). This disease is an attentional blindness, not a visual one. Hemineglect is a symptom of a broader neurological difficulty called *parietal lobe syndrome* (Bisiach & Luzzatti, 1978; Driver & Mattingley, 1998). **FIGURE 3.14** (from Bloom &

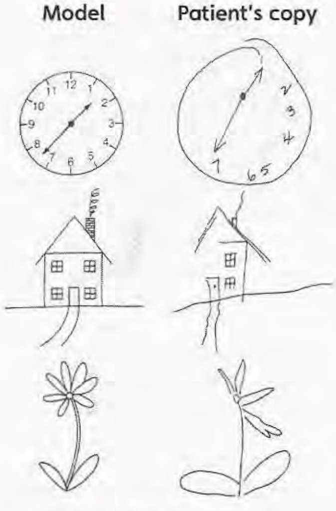


FIGURE 3.14 Pictures Drawn from Memory by a Patient with Hemineglect Patients with hemineglect typically have a stroke in their right hemisphere and cannot focus on the left side of a visual scene, as illustrated in these drawings. Their eyes do register the missing elements, but their attentional system neglects the visual input to their brains.

Source: Bloom & Lazerson (1988, p. 300)

Lazerson, 1988/2001) shows drawings made from memory by individuals with hemineglect. Notice that people with this disease draw an object from their right side and typically neglect their left side (Marshall & Halligan, 1994). When these individuals are asked to divide a picture or page in half with a vertical line, they will position the line too far to one side (Ferber & Karnath (2001).

Another test for hemineglect is to see if a person disregards one of his or her hands (left or right) when asked to take a ball and move it back and forth between the two hands. If there is consistent neglect of the left hand, this is evidence for a lesion (a structural change) in the nondominant (right) hemisphere (Driver & Mattingly, 1998). This malady is not unique to humans; hemineglect has also been shown in cats and monkeys (e.g., Payne, 1993). Curative treatments have been developed for these species (see review by Payne & Rushmore, 2003). However, the difficulties experienced by people with hemineglect can only be partially improved by medical treatment (Fleet, Valenstein, Watson, & Heilman, 1987; Hurford, Stringer, & Jann, 1998). The neurological damage is typically the result of a stroke, with the symptoms being most severe immediately after the stroke. Fortunately, the symptoms diminish with time, although the individual rarely returns to prestroke levels of functioning.

Hemineglect is clearly related to the attentional system and not the visual or auditory systems: The same objects that are neglected when they are in the left visual field are reacted to in the right field. When people begin to recover from this malady they show a peculiar pattern, similar to repetition blindness. They are asked to look straight ahead and indicate when two objects, brought from both sides of their head, appear in their periphery. When the two objects are different, say a coin and a key, they report them equally, and well within normal range for peripheral vision. However, when the two objects are identical, they fail to report one of them. Again, this is an attentional failure, not a result of a malady of the visual system.

Just because someone with hemineglect does not experience "seeing" something, that does not mean that the object does not have an unconscious effect on them. When a psychologist presents words to the left visual field of individuals with hemineglect (the left visual field corresponds to their impaired right hemisphere), the hemineglect individuals can only identify the word with great effort. However, their ability to identify the word improves with each presentation (e.g., Erickson & Allred, 2001; Ratcliff, Hockley, & McKoon, 1985). The low-level sensory information gets through the attentional filter, but the neurological problem prevents higher-level, controlled attentional processes from identifying the stimuli. These data suggest that hemineglect is the result of reduced attention, not blindness. This is one way that cognitive research has helped us to understand this troubling problem.

Attention-Deficit/Hyperactivity Disorder (ADHD)

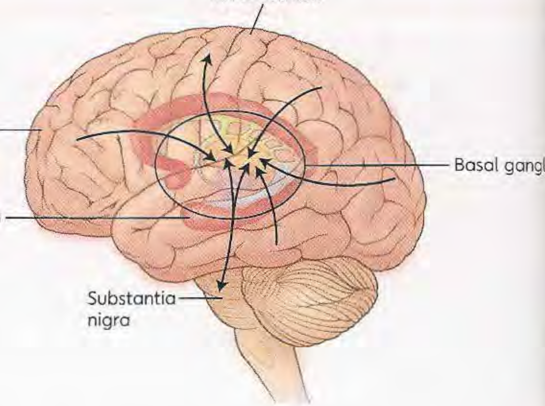
Between 3% and 10% of school-age children are affected by **attention-deficit/hyperactivity disorder (ADHD)**, a common neurobehavioral problem. Boys suffer from ADHD 2 to 3 times more often than do girls (Barkley, 1990). According to the *Diagnostic and Statistical Manual of Mental Disorders* (*DSM–IV–TR*; American Psychiatric Association, 2000) symptoms of ADHD include distractibility and inattentiveness, as well as restlessness and difficulty in self-control. For 65% of affected children, the symptoms persist into adulthood. ADHD probably has many causes. However, studies suggest that there is some genetic link: 25% of the biological parents of children with ADHD have a history of the condition, but only 4% of adoptive parents have this condition (Kendall & Hammen, 1995).

The term *attention deficit* may be a misnomer because it suggests somehow that the diagnosed children are showing neglect of stimuli. The opposite is actually the case. These children absorb or are affected by too many stimuli in their environment and have difficulty filtering out unnecessary information, so they are easily distracted. Their attentional spotlight tries to focus on too many stimuli. This is illustrated in a study by R. S. Cherry and Kruger (1983), who had children perform the kind of dichotic listening task with headsets mentioned at the beginning of this chapter. The children, ages 7 to 9, were instructed to point to the picture of a word that was presented on one channel. In the other ear, the children heard either nothing, random static, backward speech, or forward speech. Both the ADHD children and a control group of the same age performed equivalently on this task when the unattended channel was quiet. However, ADHD children performed poorly under all other conditions, and especially poorly when the unattended channel had forward speech. In contrast, the control children were unaffected by the information on the unattended channel. This illustrates that ADHD is not a failure to notice something, but a difficulty in inhibiting responsiveness to competing stimuli: Children with ADHD notice too much. From this perspective, the diagnosis of *attention deficit* ought to be called *inhibition deficit*.

Attention deficit has a biological source. In general, children with ADHD show decreased blood flow to the frontal lobes compared with age- and IQ-matched peers (Gaddes & Edgell, 1994). For years, a common practice has been to treat the condition with versions of the drug methylphenidate, an amphetamine (Ritalin®, Concerta®, Methylin®, etc.) that tends to improve concentration and reduce restlessness in about 70% of cases. This medication, like amphetamines in general, has a stimulative effect in non-ADHD populations. It therefore surprises many people that it can have a positive effect on some children with hyperactivity. The basis for its effect with ADHD populations is threefold. First, it increases blood flow to the frontal cortex, which may have an influence on increased attention. Second, the frontal cortex influences activity

FIGURE 3.15 The Dopamine Circuit Attention deficit has a biological source. An abnormally low level of the neurotransmitter dopamine can cause three of the symptoms of ADHD: inattention, impulsivity, and hyperactivity. Dopamine is produced deep within the brain in the basal ganglia, as shown in the figure. Children with ADHD have smaller basal ganglia than same-age children matched for IQ.

Source: Kolb & Whishaw (2011, p. 371)



in lower brain centers; this decreases the volume of blood in the motor cortex, thereby reducing motor activity so they are less fidgety. Third, and perhaps more important, the methylphenidate tends to maintain the availability of dopamine, an important neurotransmitter that affects attention (Volkow, Fowler, Wang, Ding, & Gatley, 2002). This is also the basis for the effectiveness of other commonly administered medications for ADHD that are amphetamine derivatives (e.g., Dexedrine®, Dextrostat®, and Adderall®).

Researchers believe that the neurotransmitter dopamine is important to ADHD because an abnormally low level of dopamine can cause three of the symptoms of ADHD: inattention, impulsivity, and hyperactivity. Dopamine, which fuels the control of these functions in the frontal lobe, is produced deep within the brain in the basal ganglia (see **FIGURE 3.15**), and children with ADHD have smaller basal ganglia than same-age children matched for IQ (e.g., Aylward et al., 1996). The importance of the neurotransmitter dopamine for attentional processes has been revealed in recent neuroimaging studies that compared the brain activity of children with ADHD with the neural activity of children with no diagnosis.

In one study (Vaidya et al., 1998) 16 boys (half diagnosed with ADHD and half without ADHD) between the ages of 8 and 13 were asked to play a mental game while lying in a magnetic resonance chamber. One of their tasks was to respond whenever a consonant (e.g., *B*, *D*, *W*) appeared on the screen, but they were not to respond when an *X* appeared. Because most of the letters were not *X*, the children developed a bias to press the button and needed to control their impulse to press the button when they saw an *X*. As shown in **FIGURE 3.16**, both groups, but especially the ADHD boys, showed widespread activation in the frontal cortex as they developed impulse control. (The greater activation in those areas for the ADHD boys may indicate how much greater effort they need to achieve good performance.)

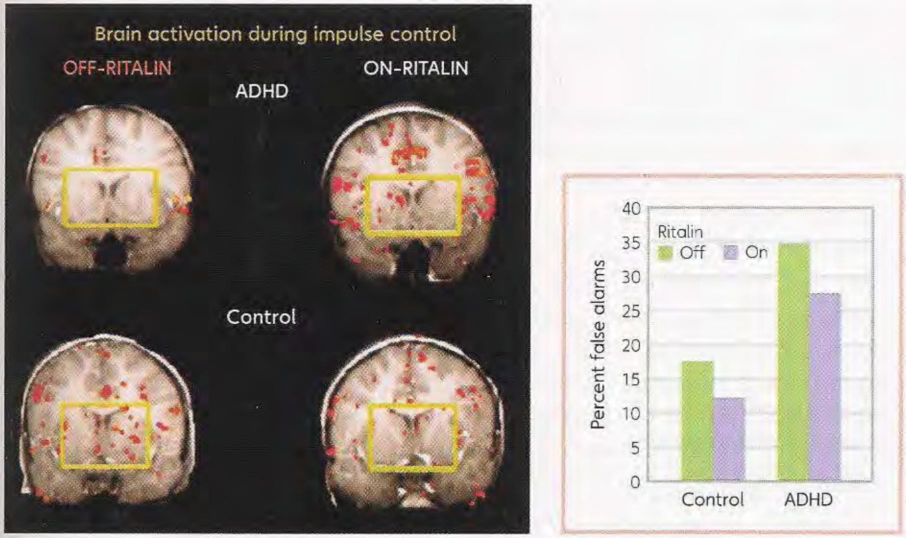


FIGURE 3.16 fMRI of Attention-Deficit/Hyperactivity Disorder During Inhibition Task The brain activity of children with ADHD is compared with the neural activity of children with no diagnosis, the control group. Both groups performed a task that measured their ability to control impulses (see text). When both groups were given Ritalin to increase their level of dopamine, they made fewer errors and increased the activity in the frontal lobes that helps self-control.

Adapted by permission from Macmillan Publishers Ltd: Molecular Psychiatry. Vaidya and Gabrieli, 1999.

The boys performed this task for two sessions, one without taking medication and one with an appropriate dose of Ritalin®. Both groups improved in their performance when taking Ritalin, but the effect of the drug was different in the brains of the two groups. The fMRI brain scans presented in the boxes outlined in yellow in Figure 3.16 show that the boys with ADHD have more activity in the structures highlighted (called the *striatum*) when taking the drug than when not, and their level of activity in this region is the same as the control group boys without a drug. When they have taken the drug, the control group boys actually show less activity in this area of the brain (Vaidya et al., 1998). This demonstrates that children with ADHD have specific brain areas that respond differently than those of children without ADHD.

Parkinson's Disease

Parkinson's disease (or **Parkinson's dementia**) is an irreversible, degenerative disease that typically affects people over 50 years of age. Mohammed Ali and Michael J. Fox are two well-known people who suffer from this disease. The readily identified symptoms of this malady are tremors when muscles are relaxed. It is this type of tremor that attracted the attention of James Parkinson (1817/2002), who described a "shaking palsy" experienced by some of his patients. However, one symptom that often goes unnoticed is the attentional difficulties that accompany advanced stages of Parkinson's. The attentional problems manifest: (a) when the patient needs to engage in activity that is not well learned or must formulate and evaluate a hypothesis; (b) when the patient needs to suppress an habitual response or resist a temptation; and (c) when the patient needs to keep focused and not be distracted in performing a task. You may notice that these symptoms are highly similar to those that are typical of children with ADHD.

These symptoms map onto circuits that involve the prefrontal cortex. Like ADHD, they involve the basal ganglia, specifically a part called the *substantia nigra* (dark substance) that contains dopamine-producing neurons (shown in Figure 3.15). Most individuals with Parkinson's disease have lost 80% of their dopamine-producing cells (R. G. Brown & Marsden, 1988, 1990; Dubois, Defontaines, Deweer, Malapani, & Pillon, 1995). This can have far-reaching effects because dopamine is probably involved in regulating many of our habitual, routine thoughts and behaviors, that require only our automatic attentional processing (Schultz et al., 1995). In addition, dopamine may be especially useful for learning and maintaining adaptive behavior in situations where several choices are available (Taylor & Saint-Cyr, 1995). Many patients respond to chemicals, such as levodopa (L-dopa), which stimulates the production of dopamine-producing cells. Another treatment is to stimulate those cells into productivity electrically using a technique called *deep brain stimulation*.

ADHD and Parkinson's dementia are two widespread conditions that affect the ability to maintain attention. The cognitive symptoms of people with ADHD and Parkinson's are similar, and so are the underlying brain mechanisms of these disorders. Further research by cognitive scientists may help medical researchers develop common treatments for these and other forms of attentional difficulties.

SECTION SUMMARY

The Neuropsychology of Attention

Attention works so seamlessly that we often are unaware of its importance until we have difficulty paying attention. A host of maladies falls under the general heading of attentional difficulties. People who suffer from simultanagnosia, for example, have difficulty switching their attention from one object to another. As a consequence they frequently bump into objects that their visual system registers, but to which their attentional system is blind. A similar malady is called hemispheric neglect. It occurs when a person's attentional system (but not the visual system) is blind to objects in half of that person's visual field, typically the left visual field. Their brains register the missing information, but their attentional system cannot react to it. For some people, paying attention is always difficult because of neurological problems. Although they do not have conscious awareness of events in the left visual field, these events can still have an unconscious influence on their behavior.

Attention-deficit/hyperactivity disorder (ADHD) is a common form of attentional difficulty in which both children and adults show distractibility. Although it is referred to as attentional deficit, its source is the inability of the attentional system to filter out irrelevant input. People with ADHD attend to too many stimuli, which suggests that it should be called inhibition deficit. It has a genetic component and is related to the presence of dopamine, a neurotransmitter that affects functioning of the frontal lobes. It is similar in many ways to Parkinson's dementia, a disease affecting roughly 1% of people over 80 years old in the United States. These individuals have difficulty switching their attention to new events or ideas.

CHAPTER SUMMARY

The term *attention* describes the cognitive processes that allow us to concentrate or focus on one set of events in our mental environment while ignoring others. When we are consciously aware of this happening, we are said to be paying attention. We are limited in how long we are able to focus our attention and it is selective: When we attend to one set of events, we stop attending to others. There are two broad types of attentional processes. The first of these, automatic processes, occurs when attention instantly reacts to signals with barely any conscious awareness or control. Automatic processes are developed with practice and experience and by themselves make minimal demands on our cognitive resources. In contrast, controlled processes are typically slow, time-consuming, and involve conscious awareness. They can place automatic processes under their control. When controlled processes interact with otherwise automatic ones, processing priorities can become confused, making us subject to potentially devastating errors and accidents.

Attention acts like a spotlight. Both automatic and controlled processes can direct where it points. At the attention spotlight's center are the events that are most important and demand the majority of our resources. The spotlight of attention is capable of moving and being attracted to different sources of stimulation based on simple visual and auditory cues, or familiar content like the sound of our own name or what is most pertinent to a situation and important to our lives. Attention works in conjunction with sensory storage, which momentarily retains what happens to us in a raw sensory form so that our attention spotlight can illuminate a portion of it. Sensory storage provides this brief form of memory for all sensory dimensions: vision, hearing, taste, and the like.

Sometimes our attentional system focuses on stimuli based on their physical characteristics (e.g., Broadbent, 1958), such as hearing a siren in the middle of the night, or based on the pertinence of an event to us, such as hearing your name spoken across a noisy room. It is as if human attention contains a filtering system that allows us to select stimulation that is worthy of further analysis from the limitless events that confront us at any moment.

Our attentional system acts like a cognitive resource that can be limited by the set of demands placed on it at any moment and what is required to replenish that resource. Life events can overwhelm our attention and make great demands on attentional resources, from which it takes considerable time to recover. During this period, our attention shuts down and we miss important stimuli. Similar blinks occur when people miss a repeated sound or word (repetition blindness) or when they focus their attention on one event and completely disregard another, potentially more important, event (as are the cases with change blindness and inattentional blindness).

The cognitive approach to attention can be applied to understanding biologically based conditions that interfere with normal attentional functioning: simultanagnosia, hemispheric neglect, Parkinson's disease, and ADHD. These and other interruptions to the smooth functioning of attention involve the frontal lobes of the brain and the neurotransmitter dopamine. Studies of neurological deficits combined with basic cognitive research have shown that paying attention to one object or event also means not paying attention to others. This is best illustrated with ADHD. The chief characteristic of ADHD is an attentional spotlight that contains too many stimuli competing for consideration, so the affected individuals have difficulty preventing themselves from attending to irrelevant events. Medications that are helpful to people with these disorders have helped psychologists understand the biology of attention.

KEY TERMS

attention, p. 45
preattentive processing (or preattentive analysis), p. 47
focused attentional processing, p. 48
orienting reflexes, p. 48
where/what circuits, p. 48
habituation, p. 49
attentional spotlight, p. 49
span of apprehension, p. 51
subitizing, p. 52
sensory storage, p. 53
sensory memory, p. 54
sensory information storage (SIS), p. 54
saccades, p. 54
capacity, p. 54
duration, p. 54
forgetting, p. 54
coding, p. 54
partial report procedure, p. 55
masking, p. 56
precategorical storage, p, 58
attentional processing, p. 58
cocktail-party phenomenon, p. 59
early-selection filter, p. 61
late-selection filter, p. 61
late-selection theory, p. 61
automatic processes, p. 62
controlled processing, p. 62
Stroop effect, p. 62
closed skill, p. 65
open skills, p. 65
mindlessness, p. 65
capacity theory of attention, p. 68
attentional blink, p. 68
repetition blindness, p. 70
change blindness, p. 71
inattentional blindness, p. 73
simultanagnosia, p. 75
hemispheric neglect (or hemineglect), p. 75
attention-deficit/ hyperactivity disorder (ADHD), p. 77
Parkinson's disease (or Parkinson's dementia), p. 79

QUESTIONS FOR REVIEW

Check Your Knowledge

1. Can you define attention?
2. How does the length of time spent performing a task affect your ability to attend to it?
3. If you were a lifeguard, how long should you stay in one place looking at a specific area of the pool before you started to miss important events?
4. What are the earliest signs of attention in the life of a child?
5. Sometimes we don't notice repeated events. What process accounts for this change in attention?
6. What are the properties of attention described by the spotlight metaphor?
7. How long does it take a typical person to move his or her attentional spotlight?
8. How wide is the spotlight in the visual domain?
9. What is subitizing?
10. How many things can we automatically identify?
11. Sensory storage is the memory system on which attention relies. Describe the four properties of this system: capacity, duration, forgetting, and coding.
12. What is the dichotic listening task (shadowing)?
13. Attention can filter out new sensory events. What is an example of an early-selection filter?
14. What is an example of a late-selection filter?
15. Define automatic processing and give an example.
16. Define controlled processing and give an example.
17. What is the difference between an open and closed skill?
18. What is the key source of danger with automatic processing?
19. What is the attentional blink and how is it affected by the age of the person?
20. What is repetition blindness?
21. What is change blindness?
22. Which type of objects' changing are you more likely to be blind to?

23. What is inattentional blindness? Choose a real-world situation that embodies this phenomenon.
24. Which is more disruptive of driving: listening to the radio or talking on a hands-free cell phone?
25. What is Bálint's syndrome and why do people who suffer this malady develop bruises?
26. Is hemineglect the result of poor eyesight? Why?
27. What is attention-deficit/hyperactivity disorder?
28. What does the text think it should be called?
29. What other neurological maladies are similar to ADHD?
30. Why do amphetamines help people with ADHD?

Apply Your Knowledge

1. What are the benefits of an attentional system with both automatic and controlled attention?
2. What would life be like if we possessed only automatic attention processes? What would life be like if we possessed only controlled attention processes?
3. Suppose you are driving on a highway, closely following the car in front of you, and you notice a police car in your mirror. Aside from the issue of getting a ticket, why does research on attention advise you to slow down and increase the distance between your car and the car in front?
4. In light of research findings on inattention, what would your advice be to people who talk on their cell phones while driving? What do you think the data imply for using hands-free versus handheld cell phones?