CHAPTER 3

Perception and Attention

hmmm...?

1. When we talk about the “computational brain,” what do we mean, and how does that relate to the survival of the human species?

2. Why are sensation and perception important topics to cognitive psychologists?

3. How do illusions help us understand the relationship between the things sensed and the things hypothesized?

4. What are iconic storage and echoic storage, and how do they help us understand the “real” world?

5. How do cognitive psychologists define attention? Name several examples of attention in everyday life.

6. What are the major theories of attention and the experimental support for them?

7. What do we mean when we talk about “processing capacity” and “selective attention”?

8. What is “automatic processing”? Give some examples of automatic processing from your everyday life experiences.

9. What have cerebral imaging techniques told us about attention?
As you woke today, you fired up your cognitive computer, which had been turned off for the night. When you were jolted out of an unconscious state by the ringing of an alarm clock, you sensed the auditory world; when you opened your eyes, you caught sight of the visual world; when you splashed water on your face, you sensed the tactile world; when you inhaled the rich aroma of freshly brewed coffee, you enjoyed the olfactory world; and when you nibbled on a fresh roll, you savored the gustatory world. Five senses—five windows to the world—only five ways to know the world. Yet, contained within those five conduits to the “real world” are the basic means by which we comprehend everything from Picasso to punk rock, not to mention the ocean’s mist, Bach, perfume, Dostoevski, peppermint candy, sunsets, and physical intimacy.

In this chapter we will find out how we humans use the computational brain to:

- Perceive information about the environment.
- Attend to the world.
- Process information during the initial stages.

We begin by examining the perception of sensory signals because this is the initial step in the processing of information. At the heart of this process is the brain, whose task it is to understand and, in effect, make sense out of the things being fed into it from the peripheral nervous system. That system is made up of nerves that lie outside the spinal cord and the brain and are involved in sensation and perception.

**The Computational Brain**

The peripheral nervous system and brain are largely designed to perceive and cogitate—to see and understand, for example. Steve Pinker expressed it well in his book *How the Mind Works*: “The mind is a system of organs of computation, designed by natural selection to solve the kinds of problems our ancestors faced in their foraging way of life, in particular, understanding and outmaneuvering objects, animals, plants, and other people” (1997, p. 21). We see, hear, smell, taste, and feel the sensations of the world as the first link in a chain of events that subsequently involves coding stimuli; storing information; transforming material; thinking; and, finally, reacting to knowledge.

The concept of the computational brain is based on the idea that the mind is what the brain does—the mind processes information. When we engage in “higher-order cognition”—thinking about the way an apple and America are alike or figuring out how to meet our friend Jean in Chile—we are doing a type of computation.

As shown in Figure 3.1, physical energy that falls within the limited range of human detection stimulates the sensory system, is transduced (converted to neural energy), is

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*If the Creator were to bestow a new set of senses upon us, or slightly remodel the present ones, leaving all the rest of nature unchanged, we should never doubt we were in another world, and so in strict reality we should be, just as if all the world besides our senses were changed.*

—John Muir
briefly held in a sensory storage, is subjected to further processing by the central nervous system (CNS) and coded, and may be passed on to memory systems for processing. The results can initiate responses that become part of the stimulus field for further processing. (A large portion of the remainder of this book deals with the very complex and abstract processing of information that takes place in the memory systems and the computation of that information.)

It is useful to keep in mind that the flowchart shown in Figure 3.1 is just a representation of the hypothetical stages through which information is processed. It is certainly not the case that the brain is arranged more or less as shown in the illustration, but this model has value as a visual conceptualization of the various stages of information processing postulated in cognitive psychology. What is key in cognitive psychology is the capability to see the activation of the brain as information is being processed. These techniques, mentioned in the previous chapter, suggest that the stages shown in this figure are analogous to actual physiological processes. With these viewing techniques, the dream of scientists throughout the twentieth century to observe the locus of brain activities associated with cognitive processes is rapidly becoming a reality. Some of these findings and trends are shown in this chapter and in later chapters on memory and higher-order cognition.

**Sensation and Perception**

The point of contact between the inner world and the external reality is centered in the sensory system. The study of the relationship between the physical changes of the world and the psychological experiences associated with these changes is called psychophysics.

The term **sensation** refers to the initial detection of energy from the physical world. The study of sensation generally deals with the structure and processes of the sensory mechanism and the stimuli that affect those mechanisms (see Table 3.1).

The term **perception**, on the other hand, involves higher-order cognition in the interpretation of the sensory information. **Sensation** refers to the initial detection of stimuli; **perception** to an interpretation of the things we sense. When we read a book, hear a concert, have a massage, smell cologne, or taste caviar, we experience far more than the
immediate sensory stimulation. Each of these sensory events is processed within the context of our knowledge of the world; our previous experiences give meaning to simple sensory experiences—that is perception.

**Illusions**

The distinction between sensations and the perceived interpretation of those experiences—in effect between what our sensory system receives and what the mind interprets—has occupied a central position in perception and cognition. It also poses a fascinating question: Why does the mind distort reality?

One line of research uses measurement of the physical and psychological quality of the same sensory stimuli. Sometimes the two measures of reality, the “real” and the perceived, do not match, as in the case of perceptual illusion. A well-known example is the Müller-Lyer illusion (see Figure 3.2), in which two equal segments of a line seem unequal. The explanation of this illusion is probably partly influenced by our past experiences, which have taught us to expect that certain shapes are far away and others close. On the other hand, some argue that this illusion (and many more like it) reflects deep-seated invariant structures of the brain. See the discussion on illusory contours in Chapter 4. A more involved type of illusion is that in the drawing by M. C. Escher shown in Figure 3.3. Here the visual cues of proximity and distance and of the behavior of running water do not appear consistent with each other.

**TABLE 3.1**

<table>
<thead>
<tr>
<th>Sense</th>
<th>Structure</th>
<th>Stimulus</th>
<th>Receptor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vision</td>
<td>Eye</td>
<td>Light waves</td>
<td>Rods and cones</td>
</tr>
<tr>
<td>Hearing</td>
<td>Ear</td>
<td>Sound waves</td>
<td>Hair cells</td>
</tr>
<tr>
<td>Taste</td>
<td>Tongue</td>
<td>Chemicals</td>
<td>Taste buds</td>
</tr>
<tr>
<td>Smell</td>
<td>Nose</td>
<td>Chemicals</td>
<td>Hair cells</td>
</tr>
<tr>
<td>Touch</td>
<td>Skin</td>
<td>Pressure</td>
<td>Nerve cells</td>
</tr>
</tbody>
</table>

**Figure 3.2**

The Müller-Lyer illusion. The line segments in A are of equal length; those in B, which appear equal, are actually unequal.
The relationship between perception and previous knowledge of the world is manifested not only in simple geometric illusions but also in the interpretation of scientific data. Figure 3.4A shows post holes found in an archaeological dig. If your knowledge of the tribe in question led you to the hypothesis that the huts had been rectangular, you would tend to “see,” or interpret, the post hole data as shown in Figure 3.4B. Conversely, other hypotheses might lead you to interpret the pattern of post holes differently, as in Figure 3.4C. Suppose you had reason to believe that the huts were triangular. Attempt an outline along those lines, selecting “relevant” and “irrelevant” post holes.
Perceptions are influenced by past knowledge, previous hypotheses, and prejudices, as well as sensory signals.

So, the way we perceive the primary information of the world is greatly influenced by the way the sensory system and brain are initially structured—we are “hard-wired” to perceive the world in a certain way—and by our past experiences, which give abundant meaning to the initial sensation of stimuli. If past learning did not influence our perception, the curious lines on this page you are now reading, which we call letters, would not be perceived as parts of words and the words would be devoid of meaning. We learn what visual (and auditory, tactical, gustatory, and olfactory) signals mean.

Sensory-Brain Predisposition

There is another side to the sensory and perceptual process that is supported by studies of the physical makeup of the sensory system and the brain. The sensory system is composed of the receptors and connecting neurons of the five senses (hearing, sight, touch, taste, and smell). Each of these senses has, to a greater or lesser degree, yielded its secrets through the effort of physiologists, physicians, and physiological psychologists throughout the past 150 years. Knowledge about the brain and its role in perception, on the other hand, has been slow to develop, partly because of the brain’s inaccessibility. Direct observation of the workings of the brain typically involved the removal of a portion of its hard calcified case, which had evolved over millennia for the very purpose of keeping the brain from harm’s way, or the postmortem scrutiny of brains by physicians interested in finding the neurological basis for symptoms. These studies indicated some gross features, such as the well-known contralaterality of the brain, which dictates that cerebral damage to one hemisphere will result in a deficiency in the opposite side of the body. Other traumatic episodes, such as getting rapped on the back of the head in the region called the occipital lobe, result in “seeing stars.” We “see” bright flashes, and yet the eye does not detect such things. Through the direct stimulation of the occipital cortex, a visual perception occurs in that part of the brain. Brain scientists have been able to observe the sensory, perceptual, and cognitive processes of the brain without removing the skull or
clobbering people on the cranium. These techniques involve both behavioral data, such as reaction time experiments, and imaging technology, as discussed in the previous chapter (PET, CT, MRI, and the like). Now it is really possible to see the workings of the brain as it perceives information about the world and how those perceptions are routed through the labyrinth of the brain.

The processing of sensory signals by the computational brain plays a role in epistemology, or the study of the origin and nature of knowledge. Some of these thoughts pose this question: What is the rationale for our sensory, perceptual, and cognitive system as a reflection of the world? The windows of the mind, the human sensory system, emerged with the physical changes that occurred in our evolving planet. Very simple organisms developed specialized cells that reacted to light, and over millions of years, those cells became more and more specific in operation until, in time, something like an eye emerged in the limpet (see Figure 3.5.). With the evolution of the eye, the brain also emerged. After all, it’s nice to see the world, but it’s even nicer to understand what the world means! The eye and other sensory organs are as stupid as the brain is wise. Conversely, a wise brain without sensory input is devoid of essential knowledge of the world. Sensations of the world and what they mean are as much a function of the biologically fixed mechanisms as they are of the past history of the observer.

Everything We Know Is Wrong

It is useful to think of the various elements of the sensory system as channels that are open to external reality. Only the sensations that are detected by our receptors are available for higher-level processing, and because the system is limited in its receptivity, our knowledge is necessarily restricted. It is likely that we overemphasize the importance of the features of our physical universe that we can detect, while underemphasizing the importance of those we do not perceive or that require special filters to facilitate their

**Figure 3.5**

A. The eye pit of a limpet.
B. The pinhole eye of a nautilus showing rudimentary receptors and nerve fibers.
transduction. Consider how our view of “reality” would change if our eyes could “see” infrared radiation but could not “see” the normally visible part of the spectrum. Would our day and night schedules be the same? What would be the effect on history, on marketing, on fashions, on philosophy—indeed, on the whole of society? Most importantly, consider the effect on how we conceptualize reality. Because we apprehend reality through such limited (hence, distorting) channels, we are forced to conclude that everything we know is wrong. However, within the limits of our sensory apparatus, we are able to rough out a descriptive system of how we process the immense amount of information that we can detect, being mindful that the reality of our immediate world is many times more bustling than that sensed.

Our view of the perceptual process, then, is that the detection and interpretation of sensory signals is determined by:

- Stimulus energy sensed by the sensory systems and brain
- Knowledge stored in memory prior to an experience.

A large portion of cognitive research is concerned with the question of how the sensory systems and brain distort sensory information. It now seems that the things stored in our memory are abstract representations of reality. The apple you see, of course, is not stored in your head. The apple is abstracted such that all the information you need to know (that is, what it looks like, smells like, feels like, tastes like, and all the other information you know about apples) is stored in your memory. The key to the processing of sensory information and its cognitive interpretation seems to be the abstraction of information. At the sensory level, information is very specific, whereas on the interpretation level, information is commonly abstract. Our view of the world is determined by the integration of what we know (in an abstract sense) with what we sense (in a specific sense). Now, we turn to another aspect of perception—the question of how much information can be detected in a moment’s glance.

**Perceptual Span**

How much we can experience at a brief exposure is called perceptual span, an early component in the processing of information. We know that the world is teeming with stimuli, a huge number of which are within the range of sensory detection. How many of these sensations are available for further processing? Much of the confusion in considering human perceptual span resulted from the failure to discriminate between two hypothetical structures—preperceptual sensory store and short-term memory.

We apparently have a sensory store that is capable of quick decisions based on brief exposure to events. Common knowledge confirms this notion. If we close our eyes, we continue to “see” the world; if a piece of music ceases, we still “hear” it; if we remove our hand from a textured surface, we still “feel” it. Each of these sensory memories fades rapidly, however, and most are soon forgotten. What are the boundaries of these transitory impressions? How long do they last? How much can be perceived in how short a time?

The first experiment investigating perceptual span dealt with vision, not only because vision is an important sense but also because it is somewhat easier to exercise
experimental control over visual than over other stimuli (touch or taste, for example). Visual studies also had a practical side in that they were related to the rapidly developing research in reading. (Many early studies of the perceptual span were concerned with the amount of information that could be apprehended in a brief period.) Javal (1878) had observed that reading was not done by smoothly scanning a line of text but was a matter of jumping from one fixation point to another. Reading, or the gathering in of textual material, took place at the fixation points, not during the jumps, or saccades (Cattell, 1886a, 1886b; Erdmann & Dodge, 1898).

These early studies indicated that the most information that could be gathered during a single exposure was about four or five letters of unconnected matter. It is important to recognize that the conclusions of these early reading studies were based on what participants reported seeing. This failed to take into consideration the possibility that the perceptual persistence was greater than four or five letters, but that the participant was conscious of—that is, recalled having perceived—only four or five. One explanation of this phenomenon of capacity being greater than recall is that at least two stages are called into play in the reporting of stimuli: (1) the perceptual span and (2) the recall of immediate impressions. Until a series of critical experiments proved it wrong, however, the immutable “fact” remained for sixty years that on average 4.5 letters constituted the perceptual span in reading.

These critical experiments had two major effects on cognitive psychology. First, our understanding of the capacity of the perceptual span was significantly changed; second, the processing of information came to be viewed as taking place in successive stages, each of which operated by different principles. This latter result was to strengthen the “boxes in the head” metaphor as a way of representing hypothetical cognitive structures. We will encounter this metaphor in later chapters.

**Iconic Storage**

Neisser (1967) called the persistence of visual impressions and their brief availability for further processing **iconic memory**. There is some question as to whether the term **memory** is properly applied to these sensory phenomena. **Memory** to many (if not most) cognitive psychologists suggests coding and storage of information in which higher-order cognitive processes are used. Although iconic memory does involve some storage, recent findings suggest that it seems to be independent of higher-order processes such as attention. Iconic storage is essentially a stack of snapshots of the visual field. Each one lasts about a second. The purpose of these snapshots is to give the brain time to catch up with the visual information it is receiving from the eye.

Many researchers have found that incoming information is accurately represented in iconic memory but disappears quickly if not passed on for further processing. The question arose whether, while making a verbal report—that is, “reading” visual information out of a rapidly fading sensory register—the participant loses some information. If this were the case, then the amount of information contained in the perceptual span would be only the amount of information that could be reported before it faded away—in other words, a joint function of iconic fading and the time required to report the visual information.
Sperling (1960) suspected that the earlier technique, in which participants were asked to report as many items as they could remember, is actually a test of what participants remember of what they saw, which may be different from what they initially perceived. The icon, or visual impression, may contain more than we can remember. To overcome the problem, Sperling developed a partial-report technique in which for 50 milliseconds a participant was presented with an array of letters such as the following:

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R G C
L X N
S B J
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If participants try to recall as much as they can of the nine letters presented, the chances are they will recall four or five. Immediately following the display of each row of letters, however, Sperling presented one of three tones—a high-, medium-, or low-pitched one. (Thus, in the foregoing example, RGC might have been cued by a high tone, LNX by a medium-pitched tone, and so on.) The tones served to cue the participant to recall the first, second, and third rows of letters, respectively. In other words, they were able to provide a "partial report" of the information. The result was that each line was recalled correctly nearly 100 percent of the time. Since the participant did not know in advance which of the three rows would be cued for recall, we can infer that all nine letters were equally available for recall; therefore, the sensory store must hold at least nine items.

Another feature of Sperling's work was that it varied the time between the display of the letters and the presentation of the tone, making it possible to gauge the length of iconic storage. If the tone was delayed more than 1 second, recall dropped to the level expected in full-report examinations (see Figure 3.6).

To estimate the decay properties of this very brief store of information, studies have been done in which one interval between the letter display and the onset of the cue (a tone or a bar marker) was varied. The effect on recall indicated that the duration of the icon is about 250 milliseconds (¼ seconds).1

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1 This is about the same time as that of the above-mentioned fixation period in reading, and some have speculated that during reading, readers briefly record visual information—words and letters—and move on to further images only after the image is recorded.

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**Figure 3.6**

Recall in relation to delay of cue.

Adapted from Sperling (1960).
If we “see” after the external physical stimulation has passed, can we “hear” after sound has passed? Apparently so. Neisser (1967) has dubbed the sensory memory for audition **echoic memory**. Echoic storage is similar to iconic storage in the sense that the raw sensory information is held in storage (in order that the pertinent features can be extracted and further analyzed) for a very short time. As with iconic storage, which allows us additional time to view fleeting stimuli, echoic storage allows us additional time to hear an auditory message. If we consider the complex process of understanding common speech, the utility of echoic storage becomes clear. Auditory impulses that make up speech are spread over time. Information contained in any small fraction of speech, music, or other sound is meaningless unless placed within the context of other sounds. Echoic storage, by briefly preserving auditory information, provides us with immediate contextual cues for comprehension of auditory information.

Although a complete description of short-term memory is presented in Chapter 6, it is important that a distinction be made here between short-term memory (STM) and echoic storage. Storage time in echoic storage is very short (between 250 milliseconds and 4 seconds); in STM it is relatively long (10–30 seconds). Auditory information is held in raw form in echoic storage and in semiprocessed form in STM.

Stereo equipment with multiple speakers was used to generate a matrix of signals that would parallel those of the visual experiments of Sperling and others. One of the first demonstrations of echoic memory came from Moray, Bates, and Barnett (1965) in their paper “Experiments on the Four-Eared Man.” The research participant (with only two ears) was placed in the center of four loudspeakers or fitted with quadrophonic earphones that permitted four messages to be presented simultaneously—much as the participant might experience sound at a party or at the center of a Beethoven string quartet. In each of these examples, a participant can attend to one voice (or signal) or another. In Moray’s experiment, the message was one to four letters of the alphabet presented simultaneously through two, three, or all four channels. As in the early visual experiments, the participant was asked to repeat as many letters as possible. In the partial-report portion of the experiment, four lights, corresponding in position to the sources of the sound, could be illuminated to cue the participant as to the channels from which he or she should recall the letters. The lights were presented 1 second after the letters. Results, indicating that recall for partial report of auditory cues was superior to that for whole reports, were interpreted as supporting the notion that auditory information was briefly held in echoic storage.

An even closer analogy to the Sperling partial-report technique is found in an experiment by Darwin, Turvey, and Crowder (1972). Through stereo headphones, participants were presented a matrix of auditory information (comparable to the visual display described earlier) consisting of three triplets of mixed random digits and letters. What the participant heard was three short lists of three items each, such as the following:

<table>
<thead>
<tr>
<th>Left Ear</th>
<th>Both Ears</th>
<th>Right Ear</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>8</td>
<td>F</td>
</tr>
<tr>
<td>2</td>
<td>6</td>
<td>R</td>
</tr>
<tr>
<td>L</td>
<td>U</td>
<td>10</td>
</tr>
</tbody>
</table>

The time for the presentation of all items was 1 second. Thus, a participant would hear, simultaneously, “B” and “8” in the left ear, and “F” and “8” in the right. The sub-
jective experience is that right- and left-ear messages can be localized as emanating from their source, and the “middle message” (which usually emanates from a signal present in both ears simultaneously) appears to come from inside the head. This technique, similar to the technique involving three visual rows used by Sperling, in effect created a “three-eared man.” Recall was measured either by means of the whole-report or partial-report techniques. A visual cue (a bar) was projected onto the left, middle, or right portion of a screen in front of the subjects. As with the visual studies, delaying the cue made it possible to trace the decay of memory. Darwin and his fellow researchers delayed the visual recall cue by 0, 1, 2, and 4 seconds; the corresponding amounts recalled are shown in Figure 3.7. Apparently, echoic storage lasts up to 4 seconds but is most vivid during the first second after auditory stimulation.

We have reviewed two of the sense modalities through which information is detected: vision and hearing. Unfortunately, not enough data have been collected on taste, olfaction, or touch to allow us to make a definitive case for or against an early perceptual memory store for these senses corresponding to the iconic and echoic storage of vision and audition. Some evidence has been presented that suggests our tactile sense involves a somewhat analogous early store (Bliss et al., 1966).

### Function of Sensory Stores

The seminal work on vision and audition has given the field of cognitive psychology important constructs that help explain the information-processing chain of events. What is the overall purpose of these brief and vivid sensory impressions of external reality? How do they fit into the larger reality of cognitive psychology?

Remarkably little attention has been directed toward integrating theories of sensory information into the larger scheme of human events. One speculation concerning iconic and echoic storage is that the extraction of information from the external, physical world follows a law of parsimony. Given the astronomical amount of sensory information that continuously excites our nervous system and the limited ability of higher-order cognitive systems to process information, only a small fraction of sensory cues can be selected for further processing.

This consideration seems to apply to vision and audition: It seems appropriate, even necessary, for the sensory system to hold information momentarily so further processing of pertinent items may take place. In reading, for example, an accurate impression of letters and
words may be necessary for comprehension, and in listening it is likely that everything from understanding conversations to appreciating music is contingent on the exact recording of auditory signals.

It seems that a delicate balance exists between selecting the appropriate information for further processing and rejecting the inappropriate information. Temporary, vivid, and accurate storage of sensory information, as exists in echoic and iconic storage, seems to provide us with a mechanism by which we can select only the pertinent information for further processing. By preserving the complete sensory impression for a brief period, we can scan the immediate events, picking out those stimuli that are most salient and fitting them into the tangled matrix of human memory. When all works properly, no more and no less information is coded, transformed, or stored than is necessary for humans to carry on a normal existence. The speculation of Edwin Boring (1946) a long time ago seems compatible with this notion: “The purpose of perception is economy of thinking. It picks out and establishes what is permanent and therefore important to the organism for its survival and welfare.”

Iconic storage, echoic storage, and storage of other sensory information allow us the opportunity to extract only the information to be subjected to further processing. The very limitations of the human nervous system prohibit the recording and processing of all, or even a sizable fraction, of the bits of information available from our brief sensory store.

Our capacity for complex processing of visual stimuli may be understood in terms of sensory storage; the ability to read may well be based on iconic storage that allows us to extract meaningful features from the visual field while discarding those extraneous stimuli that are unimportant. Similarly, our capacity to understand speech may well be based on echoic storage that allows us to hold auditory cues briefly in the presence of new ones so that abstractions can be made on the basis of phonetic context.

The development of short-term sensory stores may have been an essential component in evolution. Their function as survival mechanisms is purely speculative, but it is plausible that they allow us to perceive “everything” and yet attend to only the essential components of our percepts, making for the most economical system evolved. Sensory storage gives us the time to extract critical features for further processing and action.

**Attention**

More than a hundred years ago, William James wrote that “everyone knows what attention is.” He explained that

It is the taking possession by the mind, in clear and vivid form, of one out of what seem several simultaneously possible objects or trains of thought. Focalization, concentration of consciousness are of its essence. It implies withdrawal from some things in order to deal effectively with others. (1890, pp. 403–404)

It is improbable, of course, that he meant that we know all there is to know about attention. We did not in 1890, and we do not now. However, through a number of carefully designed experiments on attention, it has been possible to define the issues involved, and several models have emerged that present an overall perspective on the issue. This section is primarily about the emergence of attention as a component of cog-
nitive psychology and includes the exciting new developments in cognitive neuroscience. It is divided into four parts: common experiences with attention, models of attention and descriptions of the major issues of the field, a discussion of the issues and models, and the cognitive neuroscience of attention.

We shall use this general definition of attention: “the concentration of mental effort on sensory or mental events.” Research on attention seems to cover five major aspects of the topic: processing capacity and selective attention, level of arousal, control of attention, consciousness, and cognitive neuroscience.

Many of the contemporary ideas of attention are based on the premise that there are available to the human observer a myriad of cues that surround us at any given moment. Our neurological capacity is too limited to sense all of the millions of external stimuli, but even were these stimuli detected, the brain would be unable to process all of them; our information-processing capacity is too limited. Our sensory system, like other kinds of communication conduits, functions quite well if the amount of information being processed is within its capability; it fails when it is overloaded.

The modern era of attention was introduced in 1958 by Donald Broadbent, a British psychologist, who wrote in an influential book, Perception and Communication, that attention was the result of a limited-capacity information-processing system. The essential notion of Broadbent’s theory was that the world is made up of many more sensations than can be handled by the perceptual and cognitive capabilities of the human observer. Therefore, in order to cope with the flood of available information, humans selectively attend to only some of the cues and tune out much of the rest. Broadbent’s theory is discussed in some detail later in this chapter. For now, the rudiments of the model of processing can be conceptualized as a “pipeline” theory. Information, say, in the form of a human voice, enters a channel, or pipeline, and is passed along in serial order from one storage or processing system to another: from a sensory store, to a short-term storage system, and then on to a long-term storage. The original theory has been altered slightly, but the essential architecture of the system remains.

It was long thought that we can attend to one cue only at the expense of another. If we attempt to understand simultaneous messages, especially of the same kind, some

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2The impact of this work was not limited to the topic of attention but had a profound effect on the emergence of cognitive psychology as a whole.
sacrifice must be made in accuracy. For example, we may be able to attend to the highway while we drive a car (a highly practiced habit) and even listen to the radio at the same time, but it is difficult to attend simultaneously to more than one cue of the same modality—such as two auditory cues or two visual cues. It is even difficult to operate at peak performance when we are confronted with two conceptual tasks, as in the case of mentally dividing a dinner check for seven people and being asked for the time. Likely, you’ll be able to provide the time, but you’ll have to start over your tab-dividing calculation.

Our everyday experience tells us that we attend to some environmental cues more than others and that the attended cues are normally passed along for further processing, while unattended cues may not be. Which are attended to and which are not seems to stem from some control we exercise over the situation (such as looking at the instant replay to see whether the football player stepped out of bounds) and from our long-term experience (such as reading a technical report to find a certain fact). In either situation, the attention mechanism focuses on certain stimuli in preference to others, although not all of the “extraneous” stimuli are necessarily excluded entirely from attention; they may be monitored or toned down.

This is particularly evident with auditory cues, such as at a party, where we may attend to one voice while being mindful of other surrounding ones. Most of us have had the experience of having our attention drift from the voice of our conversation partner to that of someone imparting a choice bit of gossip in another conversation. It is easy to tune in to the voice recounting the gossip while we attempt to conceal our inattention to our current conversation partner.

Another case might be that of watching an opera at the point at which two characters begin “talking” (singing) at the same time. Opera abounds with such multiple signals. You may try to hear all, find it only confusing, and so tune in to one, continuing to hear, but not understanding, the other. And while you are watching a football game with all of its multiple action, it is difficult to watch all players at the same time. In the sense that we are regularly bombarded with a profusion of sensory signals and are called upon to make choices as to which are to be processed, all of one’s waking existence is comparable to these examples.

**Cognition in Everyday Life**

**The Absentminded Professor (Student?)**

Within a period of a few weeks, a professor we know applied skin cream, which was packaged in a tube almost identical to toothpaste, to his toothbrush and started brushing his teeth before realizing his error; he measured water in a coffee pot, placed the pot on the coffee maker, turned it on, and, after seeing that nothing was happening, realized he had failed to pour the water into the coffee maker’s tank; and while lecturing on kinetic art (and thinking about an experiment with dancers) used the term *kinesthetic art*. Most people do silly things like this every day.

As an exercise in critical thinking about attention, keep track of your own absentminded behaviors for several days and then organize them into types. It is likely that you will find most of the errors are due to automatic processing (your brain is on “automatic pilot”) and/or you are attending to something else (“head in the clouds”).
Five issues of attention can be identified in these examples:

1. **Processing capacity and selectiveness.** We can attend to some, but not all, cues in our external world.

2. **Control.** We have some control over the stimuli we attend to.

3. **Automatic processing.** Many routine processes (such as driving a car) are so familiar they require little conscious attention and are done automatically.

4. **Cognitive neuroscience.** Our brain and CNS are the anatomical support for attention, as well as all cognition.

5. **Consciousness.** Attention brings events into consciousness.

To use the play or football game as an example, you attend to only a minor portion of the activity. You are likely to attend selectively, focusing on some cues (such as the person who is speaking or carrying the football) more than others. One reason you attend selectively is that your ability to process information is restricted by channel capacity. Second, you have some control over which features you choose to attend to. For example, while two characters may be talking simultaneously, you can exercise some control over the one to which you will listen, or in the case of a football game, you attend to one of the players, such as the center. Third, your perception of events is related to your automatic processing of material. Fourth, recent investigations into the neurocognitive basis of attention have suggested that the attention system of the human brain is separate from other systems of the brain, such as the data processing systems. These recent discoveries have implications for cognitive theories of attention as well as serving as a bridge between neuroscience and cognitive psychology. Finally, those things that you attend to are part of your conscious experience. These five issues occupy stage center in the research on attention.

## Attention, Consciousness, and Subliminal Perception

Many theories of attention engage two controversial issues: (1) the issue of consciousness and (2) **subliminal perception**, or the effect of stimuli that are clearly strong enough to be above the physiological limen but are not conscious. As we have seen in the text, contemporary models of attention focus on where the selection of information takes place. Inherent in many of these theories is the notion that people are not aware of signals in the early part of the processing of information but, after some type of decision or selection, pass some of the signals on for further processing.

Largely stimulated by the work of Sigmund Freud, psychologists for more than a century have been interested in the dichotomy between the conscious part of the mind and the unconscious part. One problem in accepting Freud’s characterization of the dichotomous mind (especially by the behaviorists) is that such theoretical matter lacked objective substance. Nevertheless, experiments by cognitive psychologists as well as case studies from psychoanalysts have supported the dichotomous view of the mind.

The question of being able to perceive signals that are below the threshold is problematic for many research psychologists, who regard this as voodoo psychology. How can we “hear” without hearing? Yet studies of attention clearly show that it is possible to retain information that has been neglected. The topic of subliminal perception is closely related to the **priming** effect, in which the display of a word, for example, facilitates the...
recognition of an associate to that word without any conscious awareness of the process. Furthermore, several studies (Philpott & Wilding, 1979; and Underwood, 1976, 1977) have shown that subliminal stimuli may have an effect on the recognition of subsequent stimuli. Therefore, some effect of the subliminal stimuli is observed.

**Processing Capacity and Selective Attention**

The fact that we selectively attend to only a portion of all cues available is evident from various common experiences, such as those described earlier. This selectivity is often attributed to inadequate channel capacity, our inability to process all sensory cues simultaneously. This notion suggests that somewhere in the processing of information a bottleneck exists, part of which is due to neurological limitations (see Figure 3.8). Selective attention is analogous to shining a flashlight in a darkened room to illuminate the things in which we are interested while keeping the other items in the dark. With respect to the amount of information we respond to and remember, however, there appears to be a constraint in cognitive power in addition to these sensory limitations. Thus, we carefully aim the attentional flashlight, process that which we attend to, and disregard (or moderate) the other information.

Our capacity to react to a signal is related in part to how “clean” it is, that is, how free of competing information or “noise” it is. You may have become aware of the phenomenon if you have driven in parts of Canada, where major highway signs are printed in both English and French (Figure 3.9).

**F I G U R E 3 . 8**
The bottleneck in information processing.

**F I G U R E 3 . 9**
Signs in French and English.
If you attend to only one cue—say, the English—you can barrel through intricate intersections without a hint of trouble; however, if you puzzle over the compound stimulus, switching attention from one to the other, travel can be hazardous.

**Auditory Signals**

The information-processing approach to attention largely grew out of auditory research, but since that time visual as well as semantic research has emerged. Early research by Cherry (1953) led to the development of an experimental procedure called shadowing, now a standard method of studying auditory attention. In shadowing, a participant is asked to repeat a spoken message while it is presented. The task is not difficult if the rate of speech is slow, but if the speaker talks rapidly, the participant cannot repeat all the information that comes in. Cherry’s experiments, however, had an added feature: two auditory messages were simultaneously presented—one to be shadowed and the other ignored. These messages were sometimes presented through a headphone or over loudspeakers placed at different locations. Cherry (1966) observed:

> The remarkable thing is that over very wide ranges of texts [the subject] is successful, though finds great difficulty. Because the same speaker reads both messages, no clues are provided by different qualities of voice, which may help in real-life cocktail party conversation. (p. 280)

Despite the ability of participants to shadow, Cherry found that they remembered little of the shadowed message. Perhaps most of the processing of information was done in a temporary memory, so there could be no permanent storage and understanding of the message. The unattended messages were even (understandably) more poorly remembered. When the message was speech, the participants did report that they recognized it as speech, but a change from English to German in the unattended speech was not noticed. The ability to focus on one message and reduce processing from other information seems to be an important human attribute; it allows us to process a limited amount of information without overloading the capacity for information processing.

What can we conclude from Cherry’s observation? Since many of the major cues (for example, visual ones) were eliminated in his experiments, the participant must have tuned in to other cues, and these cues are thought to be related to the regularities of our language. In the course of our lifetime, we gather an immense amount of knowledge about phonetics, letter combinations, syntax, phrase structure, sound patterns, clichés, and grammar. Language can be understood when presented in one ear even when another auditory signal is presented in the other ear because we are capable of attending to contextual cues and immediately checking them with our knowledge of the language. Anomalous messages (those that don’t conform to the normal grammatical and lexical structure) must have powerful signal characteristics before being admitted. Highly familiar messages are processed more easily.

Of greater theoretical importance is the fate of the “forgotten” message. How much, if any, information sinks in from unattended channels?

In one experiment (Moray, 1959), information piped into the “deaf” ear was not retained by participants listening to the opposite channel, even though some words were repeated as many as thirty-five times. Even when Moray told them that they would be asked...
for some information from the rejected channel, they were able to report very little. Moray then took a significant step: he prefaced the message in the unattended channel with the participant’s name. Under those conditions, the message was admitted more frequently. (Isn’t this also true at a party? Someone on the other side of the room says, “And I understand that Randy’s wife . . .”. At that moment all the Randys and wives of Randys, who until then were completely engrossed in other conversations, turn a live ear to the speaker. The intrusion of an interesting event that gains one’s attention has been appropriately dubbed the cocktail party phenomenon. (Has it happened to you?)

However, the need to attend to one message is apparently strong, and with the exception of special information (like your name), little other than the attended message is admitted. There is no evidence to suggest that the ears are not being equally stimulated on the sensory level. Nor is there any evidence that one of the messages does not reach the auditory cortex. There is, however, some evidence that different parts of the cortex are involved in attention, while other parts are involved in information processing (Posner, 1988), a topic addressed later in this chapter.

Models of Selective Attention

The Filter Model: Broadbent

The first complete theory of attention was developed by Broadbent (1958). Called a filter model, the theory, related to what has been called the single-channel theory, is based on the idea that information processing is restricted by channel capacity, as originally expressed in the information-processing theory of Shannon and Weaver (1949).
Broadbent argued that messages traveling along a specific nerve can differ either according to which of the nerve fibers they stimulate or according to the number of nerve impulses they produce. (Neuropsychological studies have disclosed that high-frequency signals and low-frequency signals are carried by different fibers.) Thus, when several nerve fibers fire at the same time, several sensory messages may arrive at the brain simultaneously.

In Broadbent's model (see Figure 3.10), these would be processed through a number of parallel sensory channels. (These channels were assumed to have distinct neural codes and could be selected on the basis of that code. For example, a high-pitched signal and a low-pitched signal presented simultaneously could be distinguished on the basis of their physical characteristics even though both would reach the brain simultaneously.) Further processing of information would then occur only after the signal was attended to and passed on through a selective filter into a limited-capacity channel. In Figure 3.8 we can see that more information can enter the system than can be processed by the limited-capacity channel. Broadbent postulated that, in order to avoid an overload in this system, the selective filter could be switched to any of the sensory channels.

Intuitively, the filter theory seems valid. It is obvious that we have a limited information-processing capacity. To make some meaning out of what we hear, the brain may attend to one class of impulses (based on physical characteristics), much as a crossover filter in high-fidelity audio equipment is capable of detecting messages (electrical impulses) of one frequency level or another and sending each such message on to its respective speaker for more processing. When the situation calls for it, we can switch
our attention to another channel. However, if selection is on the basis of the physical qualities of signals, as Broadbent originally thought, then switching attention should be unrelated to the content of the message.

In an early experiment, Broadbent (1954) used the dichotic listening technique to test his theory. Research participants were presented with three digits in one ear and, at the same time, three different digits in the other ear. Thus, he or she might hear:

| Right ear | 4, 9, 3 |
| Left ear  | 6, 2, 7 |

In one condition, participants were asked to recall the digits by ear of presentation (for example, 493 and 627). In another condition, participants were asked to recall the digits in the sequence in which they appeared. Since two digits at a time were presented, the participants could recall either member of the pair first but had to report both before continuing through the sequence. Thus, in this condition, the participant could report the digits in this manner: 4, 6, 9, 2, 3, 7.

Given the amount of information to be recalled (six items) and the rate of presentation (two per second), Broadbent could expect about 95 percent recall accuracy. In both experimental conditions, recall was less than expected. In the first condition, participants were correct about 65 percent of the time; in the second, 20 percent of the time.

Broadbent interpreted the difference to be a result of having to switch attention between the sources more often in the second condition. In the first condition, where participants were asked to recall all the items from one ear and then all those from the other, they could attend to all the stimuli from one “channel” and then all those from the second (the latter, presumably, having been held briefly in some memory system). In the second condition, however, participants would have to switch their attention at least three times—for example, from left to right ear, then back from right to left, and once more from left to right.

It is easy to think of the selection process in terms of perception; however, Broadbent (1981) and others have extended the concept to memory. We all carry within us a large number of representations of past events—for example, knowledge of dozens of friends, schedules of forthcoming events, memories of past experiences, thoughts about family members, and so on. At any moment in our personal history, we can recall only a small subset of these representations, while the others remain in the background waiting to be used. Broadbent’s connection between selective perception and memory raises important theoretical as well as practical issues but, more important for our current discussion, reminds us that selective perception is not confined to a narrow range of phenomena—it touches almost every other cognitive system.

The results of an experiment by a couple of Oxford undergraduates, Gray and Wedderburn (1960), raised questions about Broadbent’s filter model. They presented to alternate ears the syllables composing a word (in sequence) and random digits, so that when a syllable was “heard” by one ear, a digit was “heard” by the other. For example:

<table>
<thead>
<tr>
<th>Left Ear</th>
<th>Right Ear</th>
</tr>
</thead>
<tbody>
<tr>
<td>OB</td>
<td>6</td>
</tr>
<tr>
<td>2</td>
<td>JEC</td>
</tr>
<tr>
<td>TIVE</td>
<td>9</td>
</tr>
</tbody>
</table>
If Broadbent’s filter theory (based on the physical nature of auditory signals) was correct, the participants, when asked to repeat what they had “heard” in one channel, should have spewed out gibberish—for example, “ob-two-tive” or “six-jec-nine”—just as participants reported 4, 6, 9, 2, 3, 7 when they heard 4 and 6 simultaneously (4 in the right ear and 6 in the left ear), and then 9 and 2, and so on. They didn’t; they said (in the case of our example), “objective,” thereby showing their capacity to switch rapidly from channel to channel.

In a second experiment (sometimes called the “Dear Aunt Jane” or “What the hell” task), Gray and Wedderburn used the same procedure but presented phrases (such as “Mice eat cheese,” “What the hell,” or “Dear Aunt Jane”) instead of syllables. For example:

<table>
<thead>
<tr>
<th>Left Ear</th>
<th>Right Ear</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dear</td>
<td>3</td>
</tr>
<tr>
<td>5</td>
<td>Aunt</td>
</tr>
<tr>
<td>Jane</td>
<td>4</td>
</tr>
</tbody>
</table>

As in the experiment with syllables and digits, the participants tended to “hear,” in this example, “Dear Aunt Jane”; thus, they apparently grouped the message segments by meaning. In Gray and Wedderburn’s words, “subjects were acting intelligently in the situation.”

It can be argued that these investigators were using a biased test, that such a task as trying to make sense out of broken words and phrases naturally caused their participants to flip-flop the channel selector in a way that is not normally done when attending to information.

A substantial test of the filter theory was made by Anne Treisman and her colleagues, whose work is described next.

### The Attenuation Model: Treisman

One problem with the filter model is the detection of sensitive or interesting information (such as your name) through an unattended channel. Moray (1959) did such an experiment and found that participants noticed their own names from the unattended channel about one-third of the time. We also know from common experience that we can monitor a second message while attending to another. A parent in church may be engrossed in a sermon heard over a background of crying in the nursery. The preaching is clearly understood, and the wails, cries, and screams of anonymous children bother not our serene parishioner. However, let the faintest whisper be emitted by the listener’s child, and that signal is heard as clearly as Gabriel’s trumpet. In fairness to Broadbent, his original theory postulated that the selection filter does occasionally admit one or two highly “probable” (likely to occur, given the context) words through the unattended channel.

To explain the fact that participants could sometimes hear their own names through the unattended channel, Moray suggested that some kind of analysis must occur before the filter. Treisman, arguing against that, suggested that in the participant’s “dictionary” (or store of words) some words have lower thresholds for activation. Thus, important words or sounds, such as one’s own name or the distinctive cry
of one’s child, are activated more easily than less important signals. Her elegant model retains much of the architecture of Broadbent’s model while accounting for the empirical results obtained by Moray.

It may be recalled that in Broadbent’s model, one channel is switched off when attention is directed to the other channel. Most noteworthy of Treisman’s work is her experiment in which participants were asked to attend to a message in one ear, while the linguistic meaning shifted from one ear to the other. For example, the message “There is a house understand the word” was presented in the right ear while “Knowledge of on a hill” was presented in the left. We tend to follow the meaning rather than attend to the message from only one ear, even when told to report the message received in that one ear. Thus, the participants reported hearing: “There is a house on a hill.” In one experiment Treisman (1964a) had French-English bilingual participants shadow a passage from Orwell’s *England, Your England*. In one ear the voice spoke in English; in the other, French. Unknown to the participants, the passages were the same but slightly offset in time. As the offset interval was gradually reduced, many participants noticed that the two messages were the same in meaning. It would appear that the “unattended” voice was not cut off from the participants’ knowledge of the second language.

Treisman’s data and those of other researchers seemed at odds with the filter model. Some cerebral “executive,” before it analyzed signal characteristics, had to make a decision to do so. Obviously, some initial screening of information must take place. According to Treisman, the first of these screens evaluates the signal on the basis of gross physical characteristics and more sophisticated screens then evaluate the signal in terms of meaning (see Figure 3.11). The initial screening takes place by means of an attenuator, or perceptual filter—a device that regulates the volume of the message and that intercedes between the signal and its verbal processing. Treisman’s model suggests that “irrelevant messages” are heard with a dull, not deaf, ear.

How well does Treisman’s attenuation model work? It is certainly a logical explanation of how we can hear something without attending to it and how we attend to meaning rather than to the physical characteristics of the message alone. However, the problem of how decisions are made remains, even if in an attenuated form. Does a simple attenuator have the capacity to analyze the intricate features of a message and check them with some master control to see whether they should or should not pass through? Furthermore, can it do all this in the twinkle of an eye necessary to keep pace with the ongoing panorama of auditory events?
These questions have sparked debate as to exactly what attributes Treisman ascribed to the attenuator. She clarified her position in a letter to the first author. With regard to the attenuator, Treisman (1986) wrote:

My suggestion was that the attenuator treats all [emphasis added] unattended messages alike, regardless of their content. The effects of probability, relevance, importance, etc., are all determined within the speech recognition system, exactly as they are for the attended message if it arrives with a low signal-to-noise ratio. . . . The only difference between unattended and attended messages is that the unattended message has its overall signal-to-noise ratio reduced by the selective filter, and therefore fails to excite lexical entries for any of its content except a few words or phrases with unusually low detection thresholds. The attenuator selects only on the basis of general physical properties such as location or voice quality. (p. 123)
Visual Attention

Thus far, we have concentrated on the auditory aspects of attention, but all sensory experiences (visual, auditory, olfactory, gustatory, and tactile) are governed by rules of attention. Vision, color, and form perception have received the greatest amount of analysis (see Chapter 4 on form perception) outside of audition. Consider the stimuli in Figure 3.12A. Here, you can “see” the cluster of +s in a field of large Ls. In experiments of this type, Treisman and her associates and Julesz (1971) and his associates have found that when visual elements are distinctive, as they are in Figure 3.12, the boundaries jump out to the viewer within 50 milliseconds—this is called the pop-out effect. This “pop-out” allows for a parallel search of the stimuli. You can take in all the information at once.

Now, look at Figure 3.12B. Here you can “see” the Ts (outlined for emphasis) with some effort, although they certainly do not jump out of the context as the +s do. Yet,

Figure 3.12

It is possible to “see” the rectangular cluster of +s in these figures (A) but more difficult to “see” the Ts (B). The first stage of attention seems to be a preattentive scanning, which surveys the general field and yields basic information, such as seeing the +s. Seeing the Ts requires focal attention.

From J. R. Bergen and B. Julesz, Nature, 303, pp. 696–698, Figure 1. Reprinted by permission.

3 Shift your attention from the visual reading of this text to another modality, say, touch, and focus on the pressure you feel on your left foot by your shoe. Think about it. Now try to center your attention on each of the other senses, and spotlight the experiences associated with each sensation.
the compositional elements are identical (that is, a + is made up of two lines at right angles to each other, as is a T). Because the visual system “sees” the Ts to be similar to the background Ls and the +s to be dissimilar, it requires a serial search of the items—you have to keep scanning the items to find the Ts.

Both Treisman and Julesz hypothesize that two different processes in visual attention are operating. In the first stage (see Figure 3.13), there is an initial, preattentive

**Figure 3.13**

A model of the stages of visual perception and attention. Initially, some basic properties of a visual scene (color, orientation, size, and distance) are encoded in separate, parallel pathways that generate feature maps. These maps are integrated into a master map. Focused attention then draws on the information from the master map to analyze in detail the features associated in a selected region of the image.

From Treisman (1988).
process (a kind of master map of an image) that scans the field and rapidly detects the main features of objects, such things as size, color, orientation, and movement, if any. Then, according to Treisman, different properties of the object are encoded in specific feature maps, which are located in different parts of the cortex.

Since the appearance of Broadbent’s original notion of attention in the 1950s, which not only influenced a whole generation of researchers including Treisman but also was important in the development of a limited-capacity model of information processing, a dozen or more theories have been put forth, all of which modify or attack some of his basic notions. Unfortunately, some have portrayed Broadbent’s theory as an either/or theory, in which information is processed either in one channel or in another. That characterization is wrong. What Broadbent (1958) wrote was “Once again we cannot say simply ‘a man cannot listen to two things at once.’ On the contrary, he receives some [emphasis added] information even from the rejected ear: but there is a limit to the amount, and details of the stimulus on the rejected ear are not recorded” (p. 23). No single theory of attention has replaced the original one, although much of the research has helped clarify specific issues involved in human attention.

**Automatic Processing**

People are confronted by myriad stimuli while at the same time participating in several activities. For example, as we drive a car, we may look at a map, scratch, talk on a cell phone, eat a hamburger, put on sunglasses, listen to music, and so on. In terms of allocation of effort, however, we are (hopefully) directing more attention to driving than to other activities, even though some attention is given to these other activities. Highly practiced activities become automatic and thereby require less attention to perform than do new or slightly practiced activities. This relationship between automatic processing and attention has been described by LaBerge (1975):

For example, imagine learning the name of a completely unfamiliar letter. This is much like learning the name that goes with the face of a person recently met. When presented
again with the visual stimulus, one recalls a time-and-place episode which subsequently produces the appropriate response. With further practice, the name emerges almost at the same time as the episode. This “short-circuiting” is represented by the formation of a direct line between the visual and name codes. The process still requires attention. . . . and the episodic code is used now more as a check on accuracy than as the mediator of the association. As more and more practice accumulates, the direct link becomes automatic (Mandler, 1954). . . . At this point the presentation of the stimulus evokes the name without any contribution by the Attention Centre. Indeed, in such cases, we often observe that we cannot prevent the name from “popping into our head.” (p. 52)

Cognition in Everyday Life

Visual Search, Automaticity, and Quarterbacks

It’s third and long, and your home team is down by 6 points late in the fourth quarter. The football is near the center of the field, and a rookie quarterback is called on to perform a task that involves a complex visual search, selection of a target, and an execution of a reasonably practiced motor act, performed under great pressure before thousands of frenzied football fans. This task, which is repeatedly performed throughout America, provides us with an interesting example of visual search, automaticity, and cognition. First, the quarterback must hold in memory a play that involves knowledge about the routes his receivers are to run. Then he must factor into his cerebral formula the defensive formation. And, finally, he must calculate the probabilities of successful candidates to receive the ball and fling the ball to that target.

Two stages of this process can be identified: A memory-retrieval task (remembering the play and routes) and a perceptual-judgment task (defensive evaluation and probabilistic judgments of success). By repeated training, each of these tasks may be vastly improved to the point that they become “automatic”—something like practiced tennis players, ballet dancers, or even chess players (see Chapter 4) perform. The trouble is that quarterbacks do not get an opportunity to practice to the degree that they can perform automatically (and about the time a professional player hones his skills to that level, his bell has been rung so many times he is ready to retire to sports announcing).

Several researchers have become interested in the automaticity problem in sports—including Arthur Fisk and Neff Walker at Georgia Institute of Technology, who have used a computer-based training system which contains film excerpts from actual games from the vantage point of the quarterback. The quarterback watches these scenes, which last about 6 to 8 seconds, and using buttons, he selects the receiver he would throw the ball to. The program then buzzes or beeps if he selects the wrong or right receiver. Another aspect of the process is actually throwing the ball and hitting a moving target. That process may be performed over and over again without a full complement of players, while the “thinking” part of the game might be turned over to computer simulation which trains people to become automatons. Perhaps in this new century all sorts of training programs will be made available for home use.
LaBerge’s concept may help account for quite a lot of human activity under stressful conditions. Norman (1976) has provided us with an apt example. Suppose that a diver is entangled in his or her scuba apparatus while beneath the surface. To survive, the diver needs to release the equipment and gradually float to the surface. Norman points out:

Practicing the release of one’s weight belt over and over again while diving in a swimming pool seems a pointless exercise to the student. But if that task can be made so automatic that it requires little or no conscious effort, then on the day that the diver needs to act under stress, the task may get performed successfully in spite of the buildup of panic. (p. 66)

For automaticity of processing to occur, there must be a free flow of information from memory to the person’s control of actions.

The automatic processing of information was given much needed structure by Posner and Snyder (1974, 1975), who describe three characteristics of an automatic process:

- An automatic process occurs without intention. In the case of the Stroop Test (a test involving words, such as RED or GREEN, that are printed in different colors in which participants are to name the color), people normally experience conflict between the two tasks and frequently read the words when asked to name the colors. Reading, a more powerful automatic process, takes some precedence over color naming and occurs without the intention of the participants. Likewise, in priming experiments, the effect operates independently of intention or conscious purpose on the part of the research participant. For example, it is easier to recognize the word NURSE after seeing the word DOCTOR.
- Automatic processes are concealed from consciousness. As pointed out in the previous example, priming effects are mostly unconscious. We do not “think” about automatic processes, which suggests the third characteristic.
- Automatic processes consume few (or no) conscious resources. We can read words or tie a knot in our shoelaces without giving these activities a thought. They take place automatically and without effort.

The importance of studies of automaticity may be that they tell us something of the complex cognitive activity that seems to occur outside of conscious experience. Furthermore, skills such as typing, scuba diving, playing the violin, driving a car, playing tennis, and even using the language correctly and making social judgments about other people are likely to be well-practiced ones that, for the most part, run automatically. Skillful performance in these matters may free consciousness to attend to the more demanding and changing onslaught of activities that require attention. The topic of automaticity engages the most enigmatic of topics in psychology: consciousness, a topic which is discussed in Chapter 5.

The Cognitive Neuroscience of Attention

As we learned in previous chapters, cognitive neuroscience represents a new direction in cognitive psychology. Stimulated by important discoveries in neurology and computer sciences, cognitive neuroscience has spread to nearly every region of cognitive psychology, including the study of attention. It is easy to think of the cognitive neuroscience study of attention as the opening of a new frontier.
Attention and the Human Brain

The connection between attention and the human brain was originally investigated by correlating attentional deficits with brain traumas. This early work was largely confined to neuropathology. For example, a lesion or stroke in one part of the brain might be associated with a type of attentional deficit. Unfortunately, pathological observations were commonly based on traumatic insults (strokes and gunshot wounds know no boundaries) and, thus, the specific locus of the brain involved in specific kinds of attention problems remained veiled. There was an additional problem in that specific pathological observations were frequently based on postmortem examinations, which allow for, to say the least, minimal interaction between the subject and observer. Pathological studies did, however, suggest that attention was partly tied to a specific cortical region. Recently, researchers interested in attention and the brain have engaged techniques, developed in both cognitive psychology and brain science, which significantly expand our understanding of this relationship. Furthermore, there is an impressive catalog of techniques to draw upon in both disciplines that do not require the subject to die, to suffer a massive stroke, to take a bullet in the head, or to surrender to a surgical procedure in order for observations to be made. The focus of these recent efforts has generally been in two areas:

1. There is the search for correlates between the geography of the brain and attentional processes (Corbetta et al., 1991; Hillyard et al., 1995; Mountcastle, 1978; Pardo, Fox, & Raichle, 1991; Posner, 1988, 1992; [especially] Posner & Petersen, 1990; Whitehead, 1991; and Woldorff et al., 1993). These studies have made use of the full range of cognitive techniques discussed in this chapter (for example, dichotic listening, shadowing, divided attention, lexical decision tasks, shape and color discrimination, and priming) and remote sensing devices used in neurological studies (for example, MRI and PET scans) as well as traditional reaction-time experiments.

2. Techniques developed in the cognitive laboratory are used as diagnostic tests or in the investigation of pharmacological agents that supposedly act selectively on the attentional process (Tinklenberg & Taylor, 1984).
Consider the matter of finding correlates between brain anatomy and attention. There appear to be anatomically separate systems of the brain that deal with attention and other systems, such as the data processing systems, that perform operations on specific inputs even when attention is directed elsewhere (Posner, 1992). In one sense, the attention system is similar to other systems (the motor and sensory systems, for example) in that it interacts with many other parts of the brain but maintains its own identity. Evidence for this conclusion can be found in patients with brain damage who demonstrate attentional problems but not processing deficits (or vice versa).

**Attention and PET**

Current research on attention has used brain imaging technology (mainly PET), and although it is impossible to report all of the recent studies (or even a reasonable cross section, so numerous are the new data in this field), it is possible to give a glimpse of some work being done in this important area of neurocognitive research by some of its foremost scientists. The basic methodological technique for PET investigations is discussed in Chapter 2. Although an explanation of the technique is not repeated here, it is important to remember that this is a procedure in which blood flow rates in the brain are evaluated by means of radioactive tracers. As the brain metabolizes nourishment through use, more blood is called for. These actions are monitored by means of radioactive sensors and transposed by a computer into a geographic map of the cortex in which “hot spots,” regions of concentrated blood flow, are identified.

Typical of these experiments is the work of Petersen and his colleagues (Petersen et al., 1990) in which research participants were shown words, nonwords that resembled words, and consonant strings. As shown in Figure 3.14, the areas activated for words and regular nonwords (but not consonant strings) were the ones shown with an oval (left figures). Curiously, patients who suffer lesions to these areas frequently are unable to read words but may read letter by letter. For example, shown the word *sand*, these patients cannot read it but can say the letters one by one (*s-a-n-d*). Through this action, the string is (probably) represented into an auditory code. Other areas of the brain take over the functioning, and these patients can say what the word is. Additional studies of the brain by means of PET show other areas involved in specific types of attention, as shown in Figure 3.14. Each of these designated areas of the brain is involved in selective attention in different ways, and to thoroughly understand the nature of the brain in attention, it is necessary to consider the topic of awareness and consciousness. The current state of knowledge of the role of the cerebral cortex in awareness and attention is that the attentional system produces the contents of awareness in the same way as other parts of the brain, such as the visual system, and organizes the way other sensations are processed, such as how the visual world is perceived.

**Spotlight on Cognitive Neuroscience**

**Visual Attention**

Paul Downing, Jia Liu, and Nancy Kanwisher (2001) use fMRI and MEG to study visual attention. Not only do they focus on finding the neural correlates of this type of cognitive
function, but they also then use that information to test theories of attention. The spatial
and temporal resolution of fMRI and MEG afford the opportunity to pinpoint the neural
locations of activity resulting from particular stimuli and task activities. Downing and his
colleagues capitalize on previous research that has shown that the fusiform face area
(FFA) of the brain responds selectively to faces and the parahippocampal place area
(PPA) responds to places and houses. Using this information, they conducted a study to
evaluate object-based attention. Using activity in FFA and PPA as dependent variables,
they had participants focus their attention to either the direction of a moving stimulus or
the position of a still item. The stimuli were a transparent house and a transparent face
superimposed one over the other. The moving stimulus was sometimes the face and
sometimes the house (with the corresponding still stimulus being the opposite). So half
of the time the participants were told to pay attention to the house and the other half of
the time to the face. They found that when participants attended to a moving house, ac-
tivity was higher in the PPA, compared to a moving face. Alternatively, when participants
attended to a moving face, activity was higher in the FFA, compared to a moving house.
When they were instructed to attend to the still item, the reverse occurred: When attend-
ing to the static face while the house was moving, activity was higher in the FFA, and
when attending to the static house while the face was moving, activity was higher in the

**Figure 3.14**

The areas of the cerebral cortex of the human brain involved in attention.
Attentional networks are shown by solid-colored shapes on the lateral (outside) and
medial (cross-sectional) surfaces of the right and left hemispheres. It appears that the
parietal lobes are involved in the attentional network (see square); the right frontal
lobes are related to vigilance; and the diamonds are part of the anterior attention
network. The oval and circle are word processing systems, which are related to visual
word form (ellipse) and semantic associations (circle).
PPA. They conclude that “task-irrelevant features in each display received more attention when they were associated with the attended object, compared to an ignored object at the same location, implicating object-based selection uniquely” (p. 1334).


**SUMMARY**

1. Cognitive psychologists are interested in perception because cognition is presumed to be a consequence of external events, sensory detection is influenced by previous experiences, and knowledge about sensory experience may tell us how information is abstracted at the cognitive level.

2. *Sensation* refers to the relationship between the physical world and its detection through the sensory system whereas *perception* involves higher-order cognition in the interpretation of sensory signals.

3. Illusions occur when one’s perception of reality is different from “reality.” Illusions are often caused by expectations based on past experiences.

4. The perceptual process consists of the detection and interpretation of reality as determined by the stimulus sensed, the structure of the sensory system and brain, and previous knowledge.

5. Studies of perceptual span concern the basic question of how much we can experience from a brief exposure.

6. Reporting stimuli perceived from a brief presentation is a dual-stage process: (1) the perception, or actual sensory registration, and (2) the recall, or ability to report what was registered before it fades.

7. Partial-report techniques address the problem of confounding sensory capacity with recall ability.

8. Iconic storage holds visual input and appears to be independent of subject control factors (for example, attention). Capacity is estimated to be at least nine items with a duration of approximately 250 milliseconds. Echoic storage holds auditory input with a duration of about 4 seconds.
9 Iconic and echoic storage may allow us to select relevant information for further processing, thus providing one type of solution to the problem of capacity limitations inherent in the information-processing system.

10 Attention is the concentration of mental effort on sensory or mental events. Many contemporary ideas about attention are based on the premise that an information-processing system’s capacity to handle the flow of input is determined by the limitations of that system.

11 Research on attention covers five major aspects: processing capacity and selectiveness, control of attention, automatic processing, the cognitive neuroscience of attention, and consciousness.

12 Capacity limits and selective attention imply a structural bottleneck in information processing. One model locates it at or just prior to perceptual analysis (Broadbent).

13 The attenuation model of selective attention proposes a perceptual filter, located between signal and verbal analyses, which screens input by selectively regulating the “volume” of the message. Stimuli are assumed to have different activation thresholds, a provision that explains how we can hear without attending.

14 Recent work in cognitive neuroscience has studied attention and has sought correlates between parts of the brain and attentional mechanisms.

**Key Words**

- attention
- automatic processing
- channel capacity
- cocktail party phenomenon
- computational brain
- echoic memory
- epistemology
- iconic memory
- perception
- perceptual span
- peripheral nervous system
- priming
- psychophysics
- saccade
- sensation
- shadowing
- subliminal perception

**Recommended Readings**