Chapter Contents

CHAPTER 6

Visual Attention

OPPOSITE PAGE This photo of PNC Park shows a Pittsburgh Pirates game in progress and the city in the background. The yellow fixation dots and red lines indicate eye movements that show where one person looked in the first 3 seconds of viewing this picture. The eye movement record indicates that this person first looked just above the right field bleachers and then scanned the ball game. Another person might have looked somewhere else, depending on his or her interests and what attracted his or her attention.
Eye movement record courtesy of John Henderson. Photo by Bruce Goldstein.

The Virtual Lab icons direct you to specific animations and videos designed to help you visualize what you are reading about. The number beside each icon indicates the number of the clip you can access through your CD-ROM or your student website.

Some Questions We Will Consider:

- Why do we pay attention to some parts of a scene but not to others? (p. 135)
- Do we have to pay attention to something to perceive it? (p. 137)
- Does paying attention to an object make the object "stand out"? (p. 142)

Look at the picture on the left, below (Figure 6.1) without looking to the right. Count the number of trees, and then immediately read the caption below the picture.

It is likely that you could describe the picture on the left much more accurately and in greater detail than the one on the right. This isn't surprising because you were looking directly at the trees on the left, and not at the hikers on the right. The point of this exercise is that as we shift our gaze from one place to another in our everyday perception of the environment, we are doing more than just "looking"; we are directing our **attention** to specific features of the environment in a way that causes these features to become more visible and deeply processed than those features that are not receiving our attention.

To understand perception as it happens in the real world, we need to go beyond just considering how we perceive isolated objects. We need to consider how observers seek out stimuli in scenes, how they perceive some things and not others, and how these active processes shape their perception of these objects and things around them.

As we describe the processes involved in attention in this chapter, we will continue our quest to understand perception as it occurs within the richness of the natural environment. We begin by considering why we pay attention to specific things in the environment. We consider some of the ways attention can affect perception and the idea that attention provides the "glue" that enables us to perceive a coherent, meaningful visual world. Finally, we will describe the connection between attention and neural firing.

Attention and Perceiving the Environment

In everyday life we often have to pay attention to a number of things at once, a situation called **divided attention**. For example, when driving down the road, you need to simultaneously attend to the other cars around you, traffic signals, and perhaps what the person in the passenger seat is saying, while occasionally glancing up at the rearview mirror. But there are limits to our ability to divide our attention. For example, reading your textbook while driving would most likely end in disaster. Although divided attention is something that does occur in our everyday experience, our main interest in this chapter will be **selective attention**—focusing on specific objects and ignoring others.

Why Is Selective Attention Necessary?

Why do we selectively focus on some things and ignore others? One possible answer is that we look at things that are interesting. Although that may be true, there is another, more basic, answer. You selectively focus on certain things in your environment because your visual system has been constructed to operate that way.

We can appreciate why attending to only a portion of the environment is determined by the way our visual system is constructed by returning to Ellen as she is walking in the woods (Figure 1.2). As she looks out at the scene before her, millions of her receptors are stimulated, and these receptors send signals out of the optic nerve and

Bruce Goldstein

Figure 6.1 How many trees are there? After counting the trees, and without moving your eyes from the picture, indicate how many of the first four hikers in the picture on the right (Figure 6.2) are males.

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Figure 6.2 Although you may have noticed that this is an outdoor scene with people walking on a road, it is necessary to focus your attention on the lead hikers to determine if they are males or females.

toward the lateral geniculate nucleus (LGN) and visual cortex. The problem the visual system faces is that there is so much information being sent from Ellen's retina toward her brain that if the visual system had to deal with all of it, it would rapidly become overloaded. To deal with this problem, the visual system is designed to select only a small part of this information to process and analyze.

One of the mechanisms that help achieve this selection is the structure of the retina, which contains the all-cone fovea (see page 50). This area supports detail vision, so we must aim the fovea directly at objects we want to see clearly. In addition, remember that information imaged on the fovea receives a disproportionate amount of processing compared to information that falls outside of the fovea because of the magnification factor in the cortex (see page 82).

How Is Selective Attention Achieved?

One mechanism of selective attention is eye movements—scanning a scene to aim the fovea at places we want to process more deeply. As we will see in the following section, the eye is moving constantly to take in information from different parts of a scene. But even though eye movements are an important mechanism of selective attention, it is also important to acknowledge that there is more to attention than just moving the eyes to look at objects. We can pay attention to things that are not directly on our line of vision, as evidenced by the basketball player who dribbles down court while paying attention to a teammate off to the side, just before she throws a dead-on pass without looking. In addition, we can look directly at something without paying attention to it. You may have had this experience: While reading a book, you become aware that although you were moving your eyes across the page and "reading" the words, you have no idea what you just read. Even though you were looking at the words, you apparently were not paying attention.

What the examples of the basketball player and reader are telling us is that there is a *mental* aspect of attention that occurs in addition to eye movements. This connection between attention and what is happening in the mind was described more than 100 years ago by William James (1890/1981), in his textbook *Principles of Psychology*:

> Millions of items . . . are present to my senses which never properly enter my experience. Why? Because they have no interest for me. My experience is what I agree to attend to. . . . 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 objects or trains of thought. . . . It implies withdrawal from some things in order to deal effectively with others.

Thus, according to James, we focus on some things to the exclusion of others. As you walk down the street, the things you pay attention to—a classmate that you recognize, the "Don't Walk" sign at a busy intersection, and the fact that just about everyone except you seems to be carrying an umbrella—stand out more than many other things in the environment. One of our concerns in this chapter is to explain why attention causes some things to stand out more than others. The first step in doing this is to describe the eye movements that guide our eyes to different parts of a scene.

What Determines How We Scan a Scene?

The first task in the study of eye movements is to devise a way to measure them. Early researchers measured eye movements using devices such as small mirrors and lenses that were attached to the eyes, so the cornea had to be anesthetized (Yarbus, 1967). However, modern researchers use camera-based eye trackers, like the one in Figure 6.3. An eye tracker determines the position of the eye by taking pictures of the eye and noting the position of a reference point such as a reflection that moves as the eye moves (Henderson, 2003; Morimoto & Mimica, 2005).

Figure 6.4 shows eye movements that occurred when an observer viewed a picture of a fountain. Dots indicate **fixations**—places where the eye pauses to take in information about specific parts of the scene. The lines connecting the dots are eye movements called **saccades**. A person who is asked to simply view a scene typically makes about three fixations per second. VL 1

What determines where we fixate in a scene? The answer to this question is complicated because our looking behavior depends on a number of factors, including characteristics of the scene and the knowledge and goals of the observer.

Stimulus Salience **Stimulus salience** refers to characteristics of the environment that stand out because of physical properties such as color, brightness, contrast, or orientation. Areas with high stimulus salience are conspicuous, such as a brightly colored red ribbon on a green Christmas tree.

Figure 6.3 A person looking at a stimulus picture in a camera-based eye tracker. *(Reprinted from* Trends in Cognitive Sciences, 7, *Henderson, John M., 498–503, (2003), with permission from Elsevier.)*

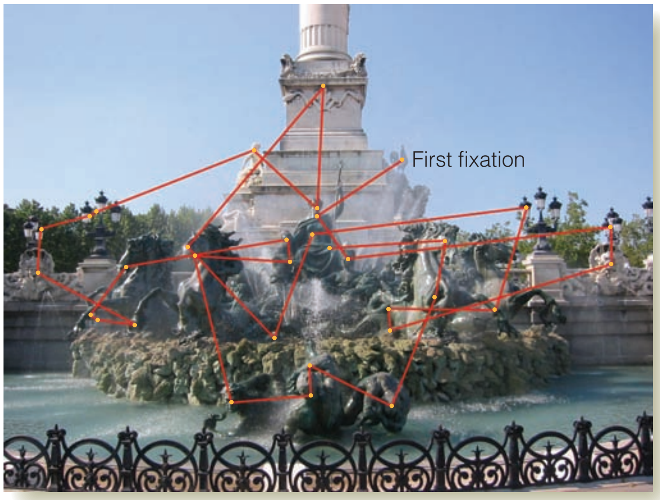


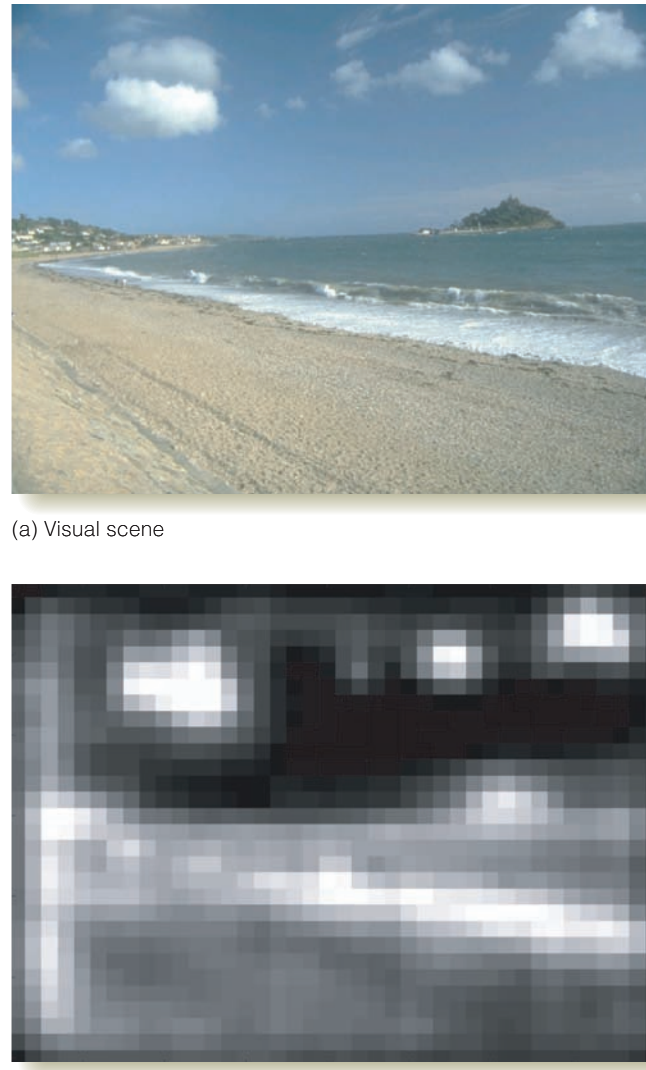
Figure 6.4 ▮ Scan path of a viewer while freely viewing a picture of a fountain in Bordeaux, France. Fixations are indicated by the yellow dots and eye movements by the red lines. Notice that this person looked preferentially at high-interest areas of the picture such as the statues and lights but ignored areas such as the fence and the sky. *(Reproduced with permission from John Henderson, University of Edinburgh.)*

Capturing attention by stimulus salience is a bottom-up process—it depends solely on the pattern of stimulation falling on the receptors. By taking into account three characteristics of the display in Figure 6.5a—color, contrast, and orientation—Derrick Parkhurst and coworkers (2002) created the **saliency map** in Figure 6.5b. To determine whether observers' fixations were controlled by stimulus saliency as indicated by the map, Parkhurst measured where people fixated when presented with various pictures. He found that the initial fixations were closely associated with the saliency map, with fixations being more likely on high-saliency areas.

But attention is not just based on what is bright or stands out. Cognitive factors are important as well. A number of cognitively based factors have been identified as important for determining where a person looks.

Knowledge About Scenes The knowledge we have about the things that are often found in certain types of scenes and what things are found together within a scene can help determine where we look. For example, consider how the observer scanned the ballpark in the chapter-opening picture facing page 133. Although we don't know the background of the particular person whose scanning records are shown, we can guess that this person may have used his or her knowledge of baseball to direct his or her gaze to the base runner leading off of first base and then to the shortstop and the runner leading off of second base. We can also guess that someone with no knowledge of baseball might scan the scene differently, perhaps even ignoring the players completely and looking at the city in the background instead.

You can probably think of other situations in which your knowledge about specific types of scenes might influence where you look. You probably know a lot, for example, about kitchens, college campuses, automobile instrument panels, and shopping malls, and your knowledge about where things are usually found in these scenes can help guide your attention through each scene (Bar, 2004).



(a) Visual scene

(b) Saliency map

Figure 6.5 ▮ (a) A visual scene. (b) Salience map of the scene determined by analyzing the color, contrast, and orientations in the scene. Lighter areas indicate greater salience. *(Reprinted from* Vision Research, 42, *Parkhurst, D., Law, K., and Niebur, E., 107–123, (2002), with permission from Elsevier.)*

Nature of the Observer's Task Recently, lightweight, head-mounted eye trackers have been developed that make it possible to track a person's eye movements as he or she perform tasks in the environment. This device has enabled researchers to show that when a person is carrying out a task, the demands of the task override factors such as stimulus saliency. Figure 6.6 shows the fixations and eye movements that occurred as a person was making a peanut butter sandwich. The process of making the sandwich begins with the movement of a slice of bread from the bag to

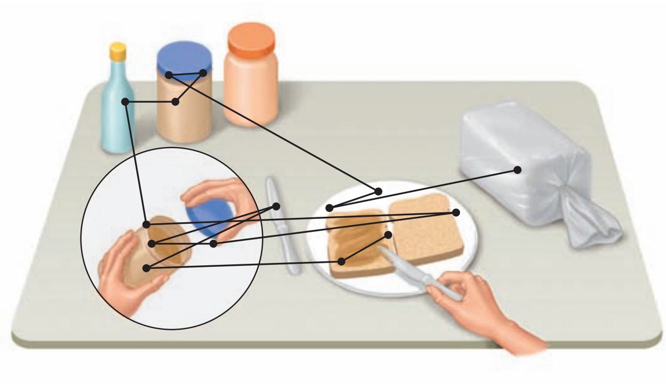


Figure 6.6 Sequence of fixations of a person making a peanut butter sandwich. The first fixation is on the loaf of bread. *(From Land, M. F., & Hayhoe, M. (2001). In what ways do eye movements contribute to everyday activities?* Vision Research, 41, *3559–3565.)*

the plate. Notice that this operation is accompanied by an eye movement from the bag to the plate. The peanut butter jar is then fixated, then lifted and moved to the front as its lid is removed. The knife is then fixated, picked up, and used to scoop the peanut butter, which is then spread on the bread (Land & Hayhoe, 2001). VL 2

The key finding of these measurements, and also of another experiment in which eye movements were measured as a person prepared tea (Land et al., 1999), was that the person fixated on few objects or areas that were irrelevant to the task and that eye movements and fixations were closely linked to the action the person was about to take. For example, the person fixated the peanut butter jar just before reaching for it (Hayhoe & Ballard, 2005).

Learning From Past Experience If a person has learned the key components of making a peanut butter sandwich, this learning helps direct attention to objects, such as the jar, the knife, and the bread, that are relevant to the task. Another example of a task that involves learning is driving. Hiroyuki Shinoda and coworkers (2001) measured observers' fixations and tested their ability to detect traffic signs as they drove through a computer-generated environment in a driving simulator. They found that the observers were more likely to detect stop signs positioned at intersections than those positioned in the middle of a block, and that 45 percent of the observers' fixations occurred close to intersections. In this example, the observer is using learning about regularities in the environment (stop signs are usually at corners) to determine when and where to look for stop signs.

It is clear that a number of factors determine how a person scans a scene. Salient characteristics may capture a person's initial attention, but cognitive factors become more important as the observer's knowledge of the meaning of the scene begins determining where he or she fixates. Even more important than *what* a scene is, is what the person is *doing* within the scene. Specific tasks, such as making a peanut butter sandwich or driving, exert strong control over where we look.

How Does Attention Affect Our Ability to Perceive?

Although there is no question that attention is a major mechanism of perception, there is evidence that we can take in some information even from places where we are not focusing our attention.

Perception Can Occur Without Focused Attention

A recent demonstration of perception without focused attention has been provided by Leila Reddy and coworkers (2007), who showed that we can take in information from a rapidly presented photograph of a face that is located off to the side from where we are attending. The procedure for Reddy's experiment is diagramed in Figure 6.7. Observers looked at the + on the fixation screen (Figure 6.7a) and then saw the *central stimulus*—an array of five letters (Figure 6.7b). On some trials, all of the letters were the same; on other trials, one of the letters was different from the other four. Observers were instructed to keep looking at the center of the array of letters. VL 3

The letters were followed immediately by the *peripheral stimulus*—either a picture of a face or a disc that was half green and half red, flashed at a random position on the edge of the screen (Figure 6.7c). The face or disc was then followed by a mask, to limit the time it was visible (see Method: Using a Mask, page 114), and then the central letter stimulus and mask were turned off.

There were three conditions in this experiment. In all three conditions, the observers were instructed to look steadily at the middle of the letter display, where the + had appeared. The face or red–green disc stimulus was presented off to the side for about 150 ms, so there was no time to make eye movements. The three conditions were as follows:

1. *Central task condition.* The letters are flashed in the center of the screen, where the observer is looking. The observer's task is to indicate whether all of the letters are the same. A face or a red–green disc is presented off to the side, but these stimuli are not relevant in this condition.

2. *Peripheral task condition.* The letters are flashed, as in the central task condition, and observers are instructed to look at the center of the letters, but the letters are not relevant in this condition. The observer's task is to indicate whether a face flashed off to the side is male or female, or if a disc flashed off to the side is red–green or green–red.

3. *Dual task condition.* As in the other conditions, observers are always looking at the center of the letter display, but they are asked to indicate both (1) if all the letters in the middle are the same and (2) for the face stimulus, whether the face is a male or a female, or for the disc stimulus, whether it is red–green or green–red.

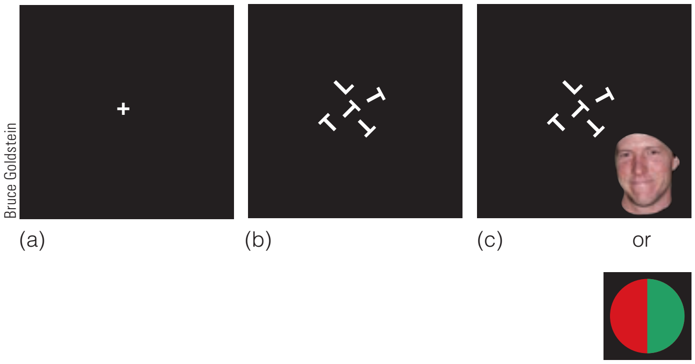


Figure 6.7 ▮ Procedure for the Reddy et al. experiment. See text for details. In (c) the peripheral stimulus was either the face or the red-green disc. *(Adapted from Reddy, L., Moradi, F., & Koch, C., 2007, Top-down biases win against focal attention in the fusiform face area,* Neuroimage 38, *730–739. Copyright 2007, with permission from Elsevier.)*

One result of this experiment, which wasn't surprising, is that when observers only had to do one task at a time, they performed well. In the central task condition and in the peripheral task condition, performance was 80–90 percent on the letter task, the face task, or the disc task.

A result that was surprising is that in the dual task condition, in which observers had to do two tasks at once, performance on the faces was near 90 percent—just as high as it was for the peripheral task condition (Figure 6.8, left bar). These results indicate that it is possible to take in information about faces even when attention is not focused on the faces.

You could argue that it might be possible to pay some attention to the faces, even when images are presented briefly off to the side. But remember that in the dual task condition observers needed to focus on the letters to perform the letter task. Also, because they did not know exactly where the pictures would be flashed, they were not able to *focus* their attention on the discs or faces. Remember, also, that the stimuli were flashed for only 150 ms, so the observers were not able to make eye movements.

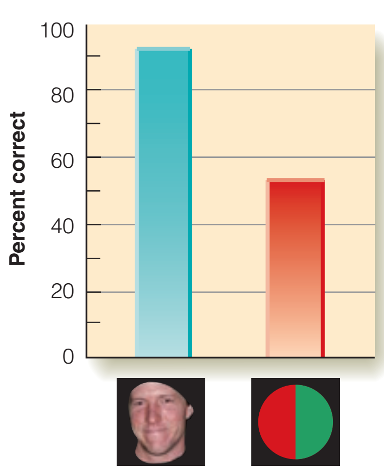


Figure 6.8 ▮ Results from the dual task condition of the Reddy and coworkers (2007) experiment. Observers were able to accurately indicate whether faces were male or female (left bar), but their performance dropped to near chance accuracy when asked to indicate whether a disc was red–green or green–red (right bar). *(Based on data from Reddy, L., Moradi, F., & Koch, C., 2007, Top-down biases win against focal attention in the fusiform face area,* Neuroimage 38, *730–739. Copyright 2007, with permission from Elsevier.)*

The observers' ability to tell whether the faces were male or female shows that some perception is possible even in the absence of focused attention. But although Reddy's observers performed with 80–90 percent accuracy for the faces in the dual task condition, performance on the red–green disc task dropped to 54 percent (chance performance would be 50 percent) in the dual task condition (Figure 6.8, right bar).

Why is it that the gender of a face can be detected without focused attention, but the layout of a red–green disc cannot? Reddy's experiment doesn't provide an answer to this question, but a place to start is to consider differences between the faces and the discs. Faces are meaningful, and we have had a great deal of experience perceiving them. There is also evidence that we initially process faces as a whole, without having to perceive individual features (Goffaux & Rossion, 2006). All of these factors—meaningfulness, experience, and perceiving as a whole—could make it possible to categorize faces as male or female without focusing attention directly on the face. Whatever mechanism is responsible for the difference in performance between faces and the red–green discs, there is no question that some types of information can be taken in without focused attention and some cannot. We will now look at some further demonstrations of situations in which perception depends on focused attention.

Perception Can Be Affected by a Lack of Focused Attention

Evidence that attention is necessary for perception is provided by a phenomenon called **inattentional blindness**—failure to perceive a stimulus that isn't attended, even if it is in full view.

Inattentional Blindness Arien Mack and Irvin Rock (1998) demonstrated inattentional blindness using the procedure shown in Figure 6.9. The observer's task is to indicate which arm of a briefly flashed cross is longer, the horizontal or the vertical. Then, on the inattention trial of the series, a small test object is flashed close to where the observer is looking, along with the cross. When observers were then given a recognition test in which they were asked to pick out the object from four alternatives, they were unable to indicate which shape had been presented. Just as paying attention to the letters in Reddy's (2007) experiment affected observers' ability to perceive the red–green disc, paying attention to the vertical and horizontal arms in Mack and Rock's experiment apparently made observers "blind" to the unattended geometric objects. VL 4

Mack and Rock demonstrated inattentional blindness using rapidly flashed geometric test stimuli. But other re-

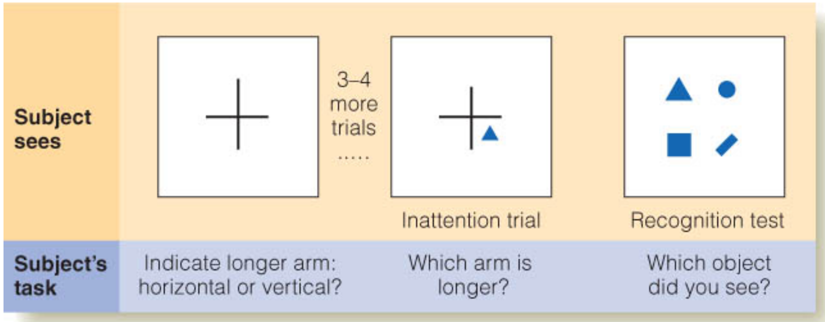


Figure 6.9 ▮ Inattentional blindness experiment. (a) Participants judge whether the horizontal or vertical arm is larger on each trial. (b) After a few trials, a geometric shape is flashed, along with the arms. (c) Then the participant is asked to pick which geometric stimulus was presented.

search has shown that similar effects can be achieved using more naturalistic stimuli that are presented for longer periods of time. Imagine looking at a display in a department store window. When you focus your attention on the display, you probably fail to notice the reflections on the surface of the window. Shift your attention to the reflections, and you become unaware of the display inside the window.

Daniel Simons and Christopher Chabris (1999) created a situation in which one part of a scene is attended and the other is not. They created a 75-second film that showed two teams of three players each. One team was passing a basketball around, and the other was "guarding" that team by following them around and putting their arms up as in a basketball game. Observers were told to count the number of passes, a task that focused their attention on one of the teams. After about 45 seconds, one of two events occurred. Either a woman carrying an umbrella or a person in a gorilla suit walked through the "game," an event that took 5 seconds.

After seeing the video, observers were asked whether they saw anything unusual happen or whether they saw anything other than the six players. Nearly half—46 percent—of the observers failed to report that they saw the woman or the gorilla. In another experiment, when the gorilla stopped in the middle of the action, turned to face the camera, and thumped its chest, half of the observers still failed to notice the gorilla (Figure 6.10). These experiments demonstrate that when observers are attending to one sequence of events, they can fail to notice another event, even when it is right in front of them (also see Goldstein & Fink, 1981; Neisser & Becklen, 1975). If you would like to experience this demonstration for yourself (or perhaps try it on someone else), go to http://viscog.beckman.uiuc.edu/media/goldstein.html or Google "gorilla experiment."

Image not available due to copyright restrictions

Change Detection Following in the footsteps of the superimposed image experiments, researchers developed another way to demonstrate how a lack of focused attention can affect perception. Instead of presenting several stimuli at the same time, they first presented one picture, then another slightly different picture. To appreciate how this works, try the following demonstration.

DEMONSTRATION

Change Detection

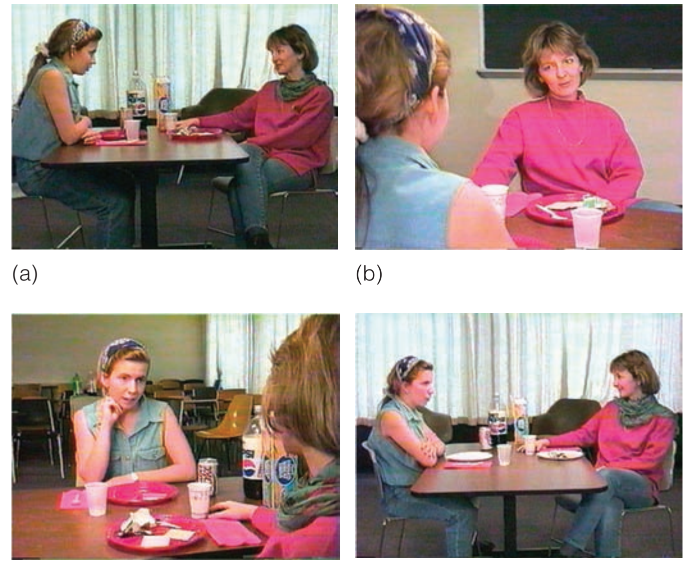
When you are finished reading these instructions, look at the picture in Figure 6.11 for just a moment, and then turn the page and see whether you can determine what is different in Figure 6.12. Do this now. ▮

Bruce Goldstein

Figure 6.11 ▮ Stimulus for change blindness demonstration. See text.

Bruce Goldstein

Figure 6.12 ▌ Stimulus for change blindness demonstration.



(a) (b) (c) (d)

Figure 6.13 ▌ Frames from a video that demonstrates change blindness. The woman on the right is wearing a scarf around her neck in shots (a), (c), and (d), but not in shot (b). Also, the color of the plates changes from red in the first three frames to white in frame (d), and the hand position of the woman on the left changes between shots (c) and (d). *(From "Failure to Detect Changes to Attended Objects in Motion Pictures," by D. Levin and D. Simons, 1997,* Psychonomic Bulletin and Review, 4, *501–506.)*

Were you able to see what was different in the second picture? People often have trouble detecting the change even though it is obvious when you know where to look. (Try again, paying attention to the sign near the lower left portion of the picture.) Ronald Rensink and coworkers (1997) did a similar experiment in which they presented one picture, followed by a blank field, followed by the same picture but with an item missing, followed by the blank field, and so on. The pictures were alternated in this way until observers were able to determine what was different about the two pictures. Rensink found that the pictures had to be alternated back and forth a number of times before the difference was detected. **VL 5–11**

This difficulty in detecting changes in scenes is called **change blindness** (Rensink, 2002). The importance of attention (or lack of it) in determining change blindness is demonstrated by the fact that when Rensink added a cue indicating which part of a scene had been changed, participants detected the changes much more quickly (also see Henderson & Hollingworth, 2003).

The change blindness effect also occurs when the scene changes in different shots of a film. Figure 6.13 shows successive frames from a video of a brief conversation between two women. The noteworthy aspect of this video is that changes take place in each new shot. In Shot (b), the woman's scarf has disappeared; in Shot (c), the other woman's hand is on her chin, although moments later, in Shot (d), both arms are on the table. Also, the plates change color from red in the initial views to white in Shot (d).

Although participants who viewed this video were told to pay close attention, only 1 of 10 participants claimed to notice any changes. Even when the participants were shown the video again and were warned that there would be changes in "objects, body position, or clothing," they noticed fewer than a quarter of the changes that occurred (Levin & Simons, 1997).

This blindness to change in films is not just a laboratory phenomenon. It occurs regularly in popular films, in which some aspect of a scene, which should remain the same, changes from one shot to the next, just as objects changed in the film shots in Figure 6.13. These changes in films, which are called *continuity errors,* are spotted by viewers who are looking for them, usually by viewing the film multiple times, but are usually missed by viewers in theaters who are not looking for these errors. You can find sources of continuity errors in popular films by Googling "continuity errors."

Change blindness is interesting not only because it illustrates the importance of attention for perception, but also because it is a counterintuitive result. When David Levin and coworkers (2000) told a group of observers about the changes that occurred in film sequences like the ones in Figure 6.13, and also showed them still shots from the film, 83 percent of the observers predicted that they would notice the changes. However, in experiments in which observers did not know which changes were going to occur, only 11 percent noticed the changes. Thus, even though people believe that they would detect such obvious changes, they fail to do so when actually tested.

One reason people think they would see the changes may be that they know from past experience that changes that occur in real life are usually easy to see. But there is an important difference between changes that occur in real life and those that occur in change detection experiments. Changes that occur in real life are often accompanied by motion, which provides a cue that indicates a change is occurring. For example, when a friend walks into a room, the person's motion attracts your attention. However, the appearance of a new object in a change detection experiment is not signaled by motion, so your attention is not attracted to the place where the object appears. The change detection experiments therefore show that when attention is disrupted, we miss changes.

To summarize this section, the answer to the question "How does attention affect our ability to perceive?" is that we can perceive some things, such as the gender of a face, without focused attention, but that focused attention is necessary for detecting many of the details within a scene and for detecting the details of specific objects in the scene.

TEST YOURSELF 6.1

1. What are two reasons that we focus on some things and ignore others? Relate your answer to the structure and function of the visual system.
2. What is selective attention? Divided attention?
3. What are the general characteristics of eye movements and fixations?
4. Describe the factors that influence how we direct our attention in a scene.
5. What does it mean to say that perception can occur without focused attention?
6. Describe the following two situations that illustrate how attention affects our ability to perceive: (1) inattentional blindness; (2) change detection.
7. What is the reasoning behind the idea that change blindness occurs because of a lack of attention? In your answer, indicate how the situation in change blindness experiments differs from the situation in which change occurs in real life.

Does Attention Enhance Perception?

William James, whose statement at the beginning of this chapter described attention as withdrawing from some things in order to deal effectively with others, did no experiments. Thus, many of the statements he made in his book *Principles of Psychology* were based purely on James's psychological insights. What is amazing about these insights is that many of them were correct. Consider, for example, James's idea that attending to a stimulus makes it more "clear and vivid." Although this idea may seem reasonable, it has only recently been confirmed experimentally. We will consider this evidence by first describing some experiments showing that paying attention increases our ability to react rapidly to a stimulus.

Effects of Attention on Information Processing

Michael Posner and coworkers (1978) were interested in answering the following question: Does attention to a specific location improve our ability to respond rapidly to a stimulus presented at that location? To answer this question, Posner used a procedure called **precueing**, as shown in Figure 6.14.

Posner's observers kept their eyes stationary throughout the experiment, always looking at the +. They first saw an arrow cue indicating on which side of the target a stimulus was likely to appear. In Figure 6.14a the cue indicates that they should focus their attention to the right. (Remember, they do this without moving their eyes.) The observer's task is to press a key as rapidly as possible when a target square is presented off to the side. The trial shown in Figure 6.14a is a *valid trial* because the square appears on the side indicated by the cue arrow. The location indicated by the arrow was

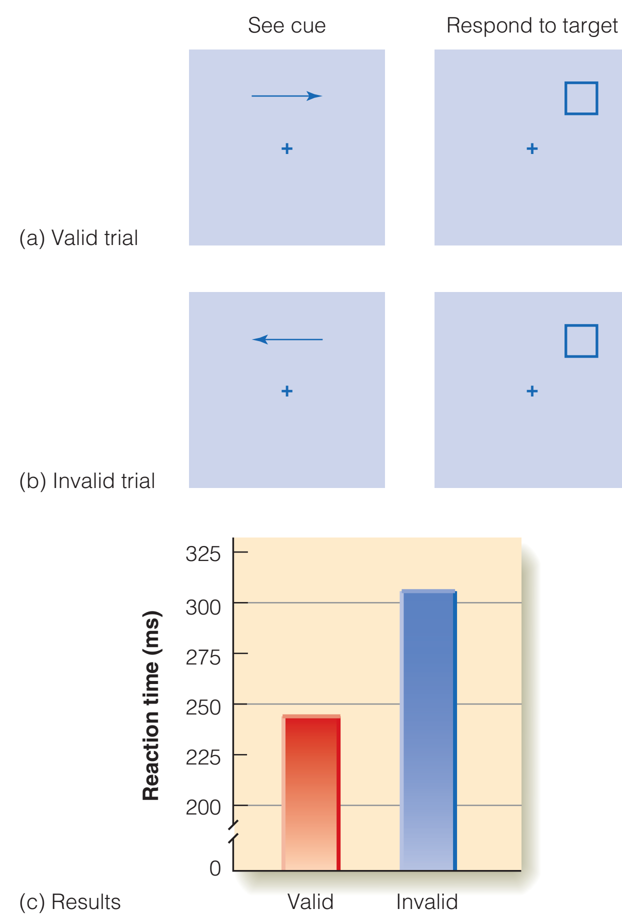


Figure 6.14 Procedure for (a) the valid task and (b) the invalid task in the Posner et al. (1978) precueing experiment; see text for details. (c) Results of the experiment: Average reaction time was 245 ms for valid trials but 305 ms for invalid trials. *(From Posner, M. I., Nissen, M. J., & Ogden, W. C., 1978, Attended and unattended processing modes: The role of set for spatial location. In H. L. Pick & I. J. Saltzman (Eds.),* Modes of perceiving and processing information. *Hillsdale, N.J.: Erlbaum.)*

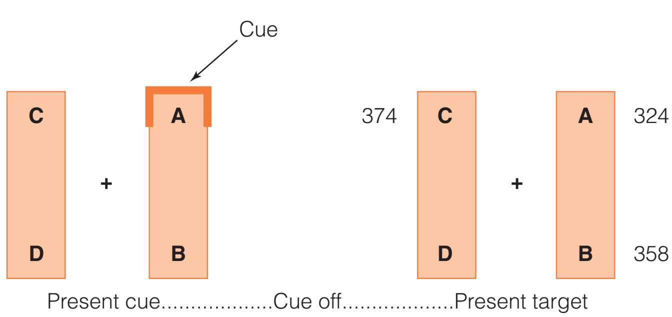
valid 80 percent of the time. Figure 6.14b shows an *invalid trial.* The cue arrow indicates that the observer should attend to the left, but the target is presented on the right.

The results of this experiment, shown in Figure 6.14c, indicate that observers react more rapidly on valid trials than on invalid trials. Posner interpreted this result as showing that information processing is more effective at the place where attention is directed.

There is also evidence that when attention is directed to one place on an object, the enhancing effect of this attention spreads throughout the object. This idea was demonstrated in an experiment by Robert Egly and coworkers (1994), in which the observer first saw two side-by-side rectangles, as shown in Figure 6.15a. As the observer looked at the +, a cue signal was flashed at one location (A, B, C, or D). After the cue signal, a target was presented at one of the positions, and the observer responded as rapidly as possible (Figure 6.15b). Reaction time was fastest when the target appeared where the cue signal had been presented (at A in this example). Like Posner's experiment, this shows that paying attention to a location results in faster responding when a target is presented at that location.

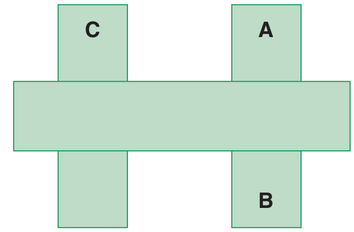
But the most important result of this experiment is that observers responded faster when the target appeared at B, which is in the same rectangle as A, than when the target appeared at C, which is in the neighboring rectangle. Notice that B's advantage occurs even though B and C are the same distance from A. Apparently the enhancing effect of attention had spread within the rectangle on the right, so when the cue was at A, some enhancement occurred at B but not at C, which was just as close but was in a different object.

The same result occurs even when a horizontal bar is added to the display, as shown in Figure 6.16a (Moore et al., 1998). Even though the bar is covering the vertical rectangles, presenting the cue at A still results in enhancement at B. What this means is that enhancement still spreads throughout the object. This "spreading enhancement" may help us perceive partially obscured objects, such as our "animal" lurking behind the tree from Chapter 5 (Figure 6.16b).

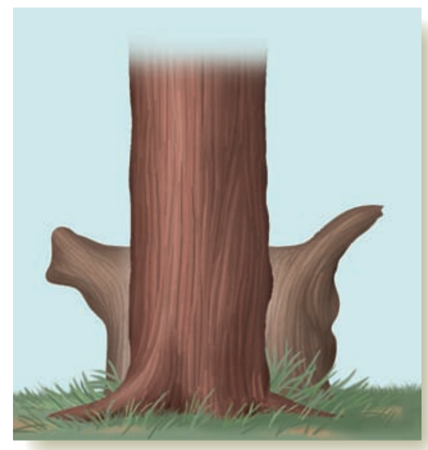


(a) (b)

Figure 6.15 ▮ In Egley et al.'s (1994) experiment, (a) a cue signal appears at one place on the display. Then the cue is turned off and (b) a target is flashed at one of four possible locations, A, B, C, or D. Numbers are reaction times in ms for positions A, B, and C when the cue appeared at position A.



(a)



(b)

Figure 6.16 ▮ (a) Stimulus in Figure 6.15, but with a horizontal bar added (Moore et al., 1998). (b) Possible animal lurking behind a tree (see Chapter 5, p. 110).

Because the effects of attention spread behind the tree, our awareness spreads throughout the object, thereby enhancing the chances we will interpret the interrupted shape as being a single object. (Also see Baylis & Driver, 1993; Driver & Baylis, 1989, 1998; and Lavie & Driver, 1996, for more demonstrations of how attention spreads throughout objects.)

Does the finding that attention can result in faster reaction times show that attention can change the *appearance* of an object, as William James suggested? Not necessarily. It is possible that the target stimulus could *appear* identical in the valid and invalid trials, but that attention was enhancing the observer's ability to *press the button* quickly. Thus, to answer the question of whether attention affects an object's *appearance,* we need to do an experiment that measures the *perceptual response* to a stimulus rather than the *speed of responding* to the stimulus.

Effects of Attention on Perception

One possible way to measure the *perceptual response* to seeing a stimulus is shown in Figure 6.17a. An observer views two stimuli and is instructed to pay attention to one of them and decide whether this attended stimulus is brighter than the other, unattended, stimulus. The stimuli could be presented at different intensities from trial to trial, and the goal would be to determine whether observers report that

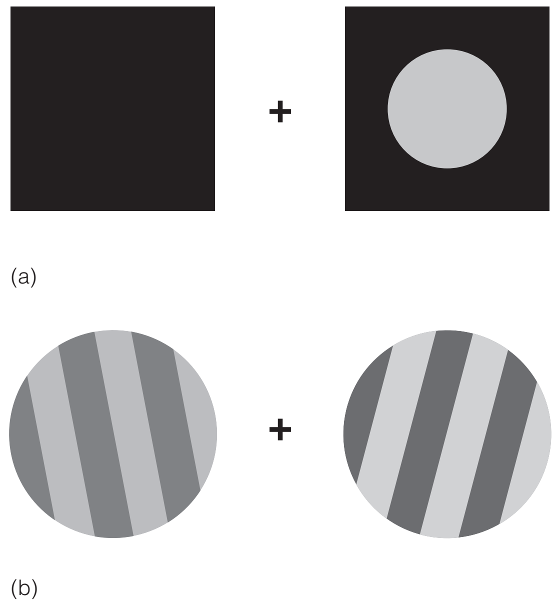


Figure 6.17 (a) Stimuli to measure how attention might affect perception. (b) A better procedure was devised by Carrasco et al. (2004), using grating stimuli.

the attended stimulus appears brighter when the two stimuli have the same intensity.

This procedure is a step in the right direction because it focuses on what the observer is *seeing* rather than on how fast the observer is reacting to the stimulus. But can we be sure that the observer is accurately reporting his or her perceptions? If the observer has a preconception that paying attention to a stimulus should make it stand out more, this might influence the observer to report that the attended stimulus appears brighter when, in reality, the two stimuli appear equally bright (Luck, 2004).

A recent study by Marissa Carrasco and coworkers (2004) was designed to reduce the possibility that bias could occur because of observers' preconceptions about how attention should affect their perception. Carrasco used grating stimuli with alternating light and dark bars, like the one in Figure 6.17b. She was interested in determining whether attention enhanced the *perceived contrast* between the bars. Higher perceived contrast would mean that there appeared to be an enhanced difference between the light and dark bars. However, instead of asking observers to judge the *contrast* of the stimuli, she instructed them to indicate the *orientation* of the grating that had the higher contrast. For the stimuli shown in the illustration, the correct response would be the grating on the right, because it has a slightly higher contrast than the one on the left. Thus, the observer had to first decide which grating had higher contrast and then indicate the orientation of that grating.

Notice that although the observer in this experiment had to decide which grating had higher contrast, they were asked to *report* the *orientation* of the grating. Having the observer focus on responding to orientation rather than to contrast reduced the chances that they would be influenced by their expectation about how attention should affect contrast.

Carrasco's observers kept their eyes fixed on the +. Just before the gratings were presented, a small dot was briefly flashed on the left or on the right to cause observers to shift their attention to that side. Remember, however, that just as in Posner's studies, observers continued to look steadily at the fixation cross. When the two gratings were presented, the observer indicated the orientation of the one that appeared to have more contrast.

Carrasco found that when there was a large difference in contrast between the two gratings, the attention-capturing dot had no effect. However, when two gratings were physically identical, observers were more likely to report the orientation of the one that was preceded by the dot. Thus, when two gratings were actually the same, the one that received attention appeared to have more contrast. More than 100 years after William James suggested that attention makes an object "clear and vivid," we can now say that we have good experimental evidence that attention does, in fact, enhance the appearance of an object. (Also see Carrasco, in press; Carrasco et al., 2006.)

Attention and Experiencing a Coherent World

We have seen that attending to an object brings it to the forefront of our consciousness and may even alter its appearance. Furthermore, not attending to an object can cause us to miss it altogether. We now consider yet another function of attention, one that is not obvious from our everyday experience. This function of attention is to help create **binding**, which is the process by which features—such as color, form, motion, and location—are combined to create our perception of a coherent object.

Why Is Binding Necessary?

We can appreciate why binding is necessary by remembering our discussion of modularity in Chapter 4, when we learned that separated areas of the brain are specialized for the perception of different qualities. In Chapter 4 we focused on the inferotemporal (IT) cortex, which is associated with perceiving forms. But there are also areas associated with motion, location, and possibly color (the exact location of a color area, if it exists, is still being researched) located at different places in the cortex.

Thus, when you see a red ball roll by, cells sensitive to the ball's shape fire in the IT cortex, cells sensitive to movement fire in the medial temporal (MT) cortex, and cells sensitive to color fire in other areas (Figure 6.18). But even though the ball's shape, movement, and color cause firing in different areas of the cortex, you don't perceive the ball as separated shape, movement, and color perceptions. You experience an integrated perception of a ball, with all of these components occurring together.

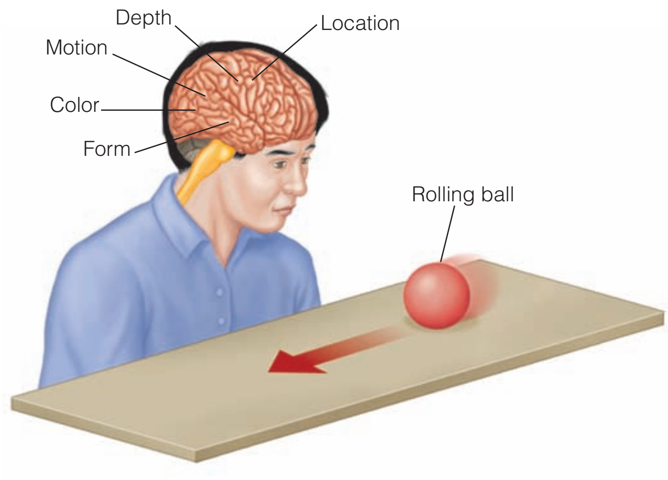


Figure 6.18 ▌ Any stimulus, even one as simple as a rolling ball, activates a number of different areas of the cortex. Binding is the process by which these separated signals are combined to create a unified percept.

This raises an important question: How do we combine all of these physically separated neural signals to achieve a unified perception of the ball? This question, which is called the **binding problem**, has been answered at both the behavioral and physiological levels. We begin at the behavioral level by describing feature integration theory, which assigns a central role to attention in the solution of the binding problem.

Feature Integration Theory

Feature integration theory, originally proposed by Anne Treisman and Garry Gelade (1980; also see Treisman, 1988, 1993, 1999), describes the processing of an object by the visual system as occurring in two stages (Figure 6.19).[1] The first stage is called the **preattentive stage** because it does not depend on attention. During this stage, which occurs so rapidly that we're not aware of it, an object is broken down into features such as color, orientation, and location.

The second stage is called the **focused attention stage** because it does depend on attention. In this stage, the features are recombined, so we perceive the whole object, not individual features.

Treisman links the process of binding that occurs in the focused attention stage to physiology by noting that an object causes activity in both the *what* and *where* streams of the cortex (see page 88). Activity in the *what* stream would include information about features such as color and form. Activity in the *where* stream would include information about location and motion. According to Treisman, attention is the "glue" that combines the information from the *what* and *where* streams and causes us to perceive all of the features of an object as being combined at a specific location.

[1] This is a simplified version of feature integration theory. For a more detailed description of the model, which also includes "feature maps" that code the location of each of an object's features, see Treisman (1999).

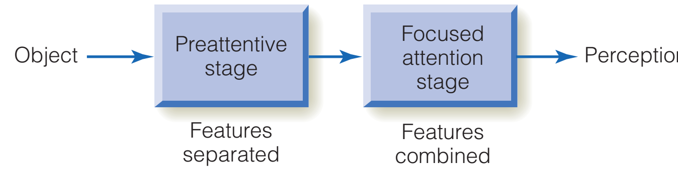


Figure 6.19 ▌ Flow diagram of Treisman's (1988) feature integration theory.

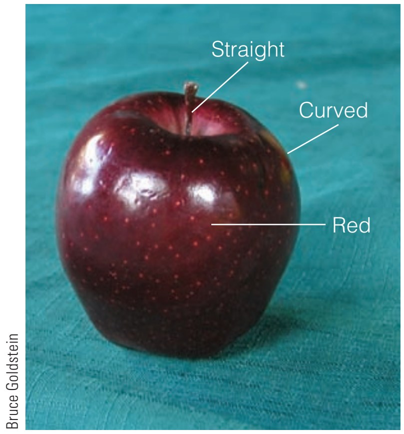
Let's consider how this might work for the object in Figure 6.20a. All of this object's features are registered as being located in the same area because this is the only object present. When we pay attention to the object, its features are all combined at that location, and we perceive the object. This process is simple because we are dealing with a single object at a fixed location. However, things become more complicated when we introduce multiple objects, as normally occurs in the environment.

When we consider multiple objects, numerous features are involved, and these features exist at many different locations (Figure 6.20b). The perceptual system's task is to associate each of these features with the object to which it belongs. Feature integration theory proposes that in order for this to occur, we need to focus our attention on each object in turn. Once we attend to a particular location, the features at that location are bound together and are associated with the object at that location.

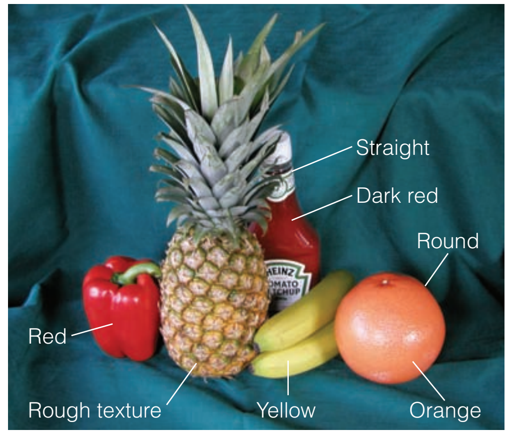
What evidence supports the idea that focused attention is necessary for binding? One line of evidence, **illusory conjunctions**, is based on the finding that under some conditions, features associated with one object can become incorrectly associated with another object.

Illusory Conjunctions Illusory conjunctions were first demonstrated in an experiment by Treisman and Schmidt (1982), which used a stimulus display of four objects flanked by two black numbers, as shown in Figure 6.21. They flashed this display onto a screen for one-fifth of a second, followed by a random-dot masking field designed to eliminate any residual perception that might remain after the stimuli were turned off. Observers were told to report the black numbers first and then to report what they saw at each of the four locations where the shapes had been. Under these conditions, observers reported seeing illusory conjunctions on 18 percent of the trials. For example, after being presented with the display in Figure 6.21, in which the small triangle was red and the small circle was green, they might report seeing a small red circle and a small green triangle.

Although illusory conjunctions may seem like a phenomenon that would occur only in the laboratory, Treisman (2005) relates a situation in which she perceived illusory conjunctions in the environment. After thinking she'd seen a bald-headed man with a beard, she looked again and realized that she had actually seen two men—one bald and one with a beard—and had combined their features to create an illusory bald, bearded man.



(a)



(b)

Figure 6.20 ▮ (a) A single object. Binding features is simple in this case because all of the features are at one location. (b) When multiple objects with many features are present, binding becomes more complicated.

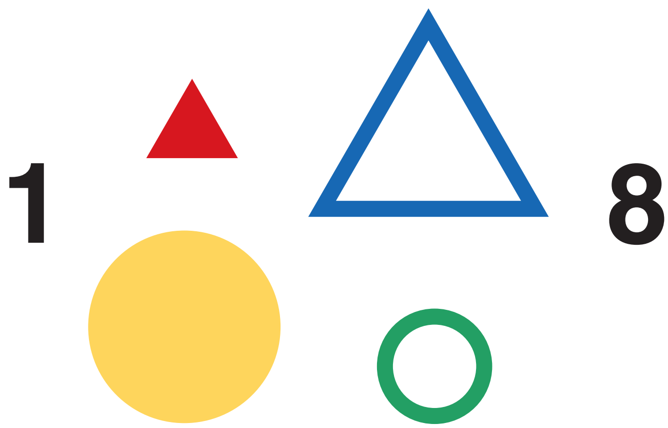


Figure 6.21 ▮ Stimuli for Treisman and Schmidt's (1982) illusory conjunction experiment.

The reason illusory conjunctions occurred for the stimuli in Figure 6.21 is that these stimuli were presented rapidly, and the observers' attention was distracted from the target object by having them focus on the black numbers. Treisman and Schmidt found, however, that asking their observers to attend to the target objects eliminated the illusory conjunctions.

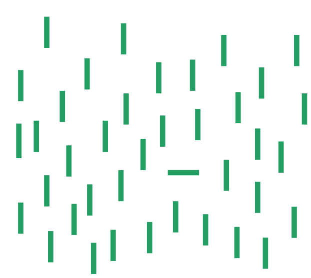
More evidence that supports the idea that illusory conjunctions are caused by a failure of attention is provided by studies of patient R.M., who had parietal lobe damage that resulted in a condition called **Balint's syndrome**. The crucial characteristic of this syndrome is an inability to focus attention on individual objects. According to feature detection theory, lack of focused attention would make it difficult for R.M. to combine features correctly, and this is exactly what happened. When R.M. was presented with two different letters of different colors, such as a red T and a blue O, he reported illusory conjunctions such as "blue T" on 23 percent of the trials, even when he was able to view the letters for as long as 10 seconds (Friedman-Hill et al., 1995; Reddy et al., 2006; Robertson et al., 1997).

Visual Search Another approach to studying the role of attention in binding has used a task called visual search. **Visual search** is something we do anytime we look for an object among a number of other objects, such as looking for a friend in a crowd or trying to find Waldo in a "Where's Waldo?" picture (Handford, 1997). A type of visual search called a *conjunction search* has been particularly useful in studying binding.

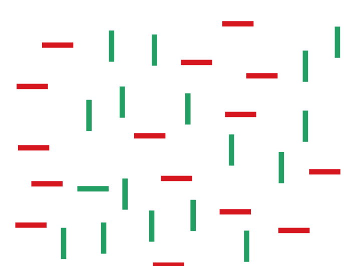
DEMONSTRATION

Searching for Conjunctions

We can understand what a conjunction search is by first describing another type of search called a *feature search.* Before reading further, look at Figure 6.22, and find the horizontal line in (a) and the green horizontal line in (b). The search you carried out in Figure 6.22a was a **feature search** because the target can be found by looking for a single feature—"horizontal." In contrast, the search you carried out



(a)



(b)

Figure 6.22 ▮ Find the horizontal line in (a) and then the green horizontal line in (b).

in Figure 6.22b was a **conjunction search** because it was necessary to search for a combination (or conjunction) of two or more features in the same stimulus—"horizontal" and "green." In Figure 6.22b, you couldn't focus just on green because there are vertical green lines, and you couldn't focus just on horizontal because there are horizontal red lines. You had to look for the *conjunction* of horizontal and green.

Conjunction searches are useful for studying binding because finding the target in a conjunction search involves focusing attention at a specific location. To test the idea that attention to a location is required for a conjunction search, a number of researchers have tested the Balint's patient R.M. and have found that he cannot find the target when a conjunction search is required (Robertson et al., 1997). This is what we would expect, because of R.M's difficulty in focusing attention. R.M. can, however, find targets when only a feature search is required, as in Figure 6.22a, because attention-at-a-location is not required for this kind of search.

The link between the parietal lobe, which is damaged in patients with Balint's syndrome, and conjunction searches is also supported by the fact that other patients with parietal lobe damage also have difficulty performing conjunction searches (Ashbridge et al., 1999). In addition, carrying out a conjunction search activates the parietal lobe in people without brain damage (Shafritz et al., 2002). This connection between the parietal lobe and conjunction searches makes sense when we remember that the parietal lobe is the destination of the *where* stream, which is involved in determining the locations of objects.

In conclusion, behavioral evidence suggests that it is necessary to focus attention at a location in order to achieve binding. We will now consider how the binding problem has been approached physiologically.

The Physiological Approach to Binding

To solve the binding problem, the brain must combine information contained in neurons that are located in different places. For example, in the case of our rolling red ball, the brain must combine information from separate areas that are activated by form, color, and motion. Anatomical connections between these different areas enable neurons in these areas to communicate with one another (Gilbert & Wiesel, 1989; Lamme & Roelfesma, 2000). But what is it that they communicate?

One physiological solution to the binding problem, the **synchrony hypothesis**, states that when neurons in different parts of the cortex are firing to the same object, the pattern of nerve impulses in these neurons will be synchronized with each other. For example, consider the two "objects" in Figure 6.23—the woman and the dog. The image of the woman on the retina activates neurons in a number of different places in the visual cortex. The activity in two of the neurons activated by the woman is indicated by the blue firing records. The image of the dog activates other neurons,

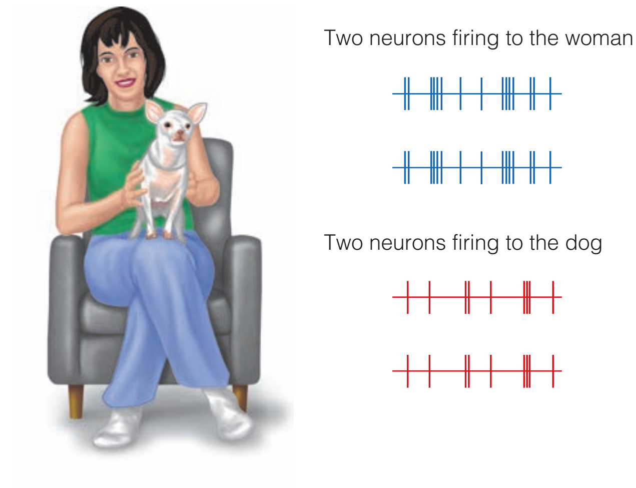


Figure 6.23 How synchrony can indicate which neurons are firing to the same object. See text for explanation. *(Based on Engel, A. K., Fries, P., Konig, P., Brecht, M., & Singer, W. (1999). Temporal binding, binocular rivalry, and consciousness.* Consciousness and Cognition, 8, *128–151.)*

which fire as indicated by the red records. Notice that the neurons associated with the woman have the same *pattern* of firing, and the neurons associated with the dog also have a common pattern of firing (but one that differs from the firing pattern associated with the woman). The similarity in the patterns of firing in each group of neurons is called **synchrony**. The fact that the two neurons activated by the woman have this property of synchrony tells the brain that these two neurons represent the woman; the same situation occurs for the neurons representing the dog.

Although attention is not a central part of the synchrony hypothesis, there is evidence that paying attention to a particular object may increase the synchrony among neurons representing that object (Engel et al., 1999). Perhaps further research will enable us to draw connections between the behavioral explanation of binding, which emphasizes the role of attention, and the physiological explanation, which emphasizes synchrony of neural firing. Note, however, that even though there is a great deal of physiological evidence that synchrony does occur in neurons that are associated with the same object (Brosch et al., 1997; Engel et al., 1999; Neuenschwander & Singer, 1996; Roskies, 1999), the synchrony hypothesis is not accepted by all researchers. More research is necessary to determine whether synchrony is, in fact, the signal that causes binding to occur.

The Physiology of Attention

How does attention affect neurons in the visual system? This question has attracted a great deal of research. We will focus here on one of the main conclusions from this research—that attention enhances the firing of neurons.

The results of a typical experiment are shown in Figure 6.24. Carol Colby and coworkers (1995) trained

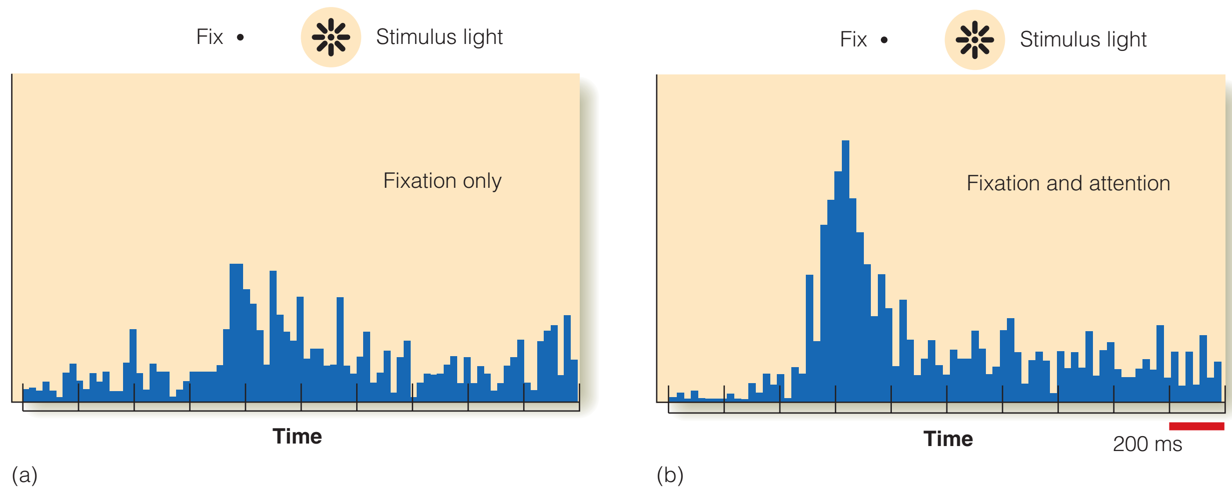


Figure 6.24 ▮ The results of Colby et al.'s (1995) experiment showing how attention affects the responding of a neuron in a monkey's parietal cortex. The monkey always looked at the dot marked "Fix." A stimulus light was flashed within the circle off to the side. (a) Nerve firing when monkey was not paying attention to the light. (b) Nerve firing when monkey was paying attention to the light. *(Reprinted from Colby, C. L., Duhamel, J.-R, & Goldberg, M. E. (1995). Oculocentric spatial representation in parietal cortex.* Cerebral Cortex, 5, *470–481. Copyright © 1995, with permission from Oxford University Press.)*

a monkey to continually look at the small fixation light marked "Fix." As the monkey looked at this light, a stimulus light was flashed at a location off to the right. In the *fixation only* condition (Figure 6.24a), the monkey's task was to release its hand from a bar when the *fixation light* was dimmed. In the *fixation and attention* condition (Figure 6.24b), the monkey continued looking at the fixation light but had to release the bar when the *stimulus light* was dimmed. Thus, in the *fixation and attention* condition, the monkey was looking straight ahead, but had to pay attention to the stimulus light located off to the side.

As the monkey was performing these tasks, Colby recorded from a neuron in the parietal cortex that fired to the stimulus light. The records in Figure 6.24 show that this neuron responded poorly to the flashing of the stimulus light in the *fixation only* condition, but responded well to the light in the *fixation and attention* condition. Because the monkey was always looking at the fixation light, the images of the fixation and stimulus lights were always the same on the monkey's retina. Thus, the greater response when the monkey was paying attention to the stimulus light must have been caused not by any change of the stimulus on the monkey's retina, but by the monkey's *attention* to the light. This means that the firing of a neuron depends on more than just the shape or size or orientation of a stimulus. It also depends on whether the animal is paying attention to the stimulus.

This enhancement of responding by attention has been demonstrated in many single-unit recording experiments on animals (Bisley & Goldberg, 2003; Moran & Desimone, 1985; Reynolds & Desimone, 2003) and also in brain imaging experiments on humans (Behrmann et al., 2004; Downar et al., 2001; Kastner et al., 1999). The single-unit experiments show that although the enhancement effect occurs as early in the visual system as the striate cortex, V1, the effect becomes stronger at higher areas in the visual system (Figure 6.25). This makes sense because higher areas are more likely to reflect an observer's knowledge of characteristics of an object such as its meaning or behavioral significance (Gottlieb et al., 2002).

We can appreciate the connection between the behavioral significance of an object and attention by considering an experiment by Daniel Sheinberg and Nikos Logothetis

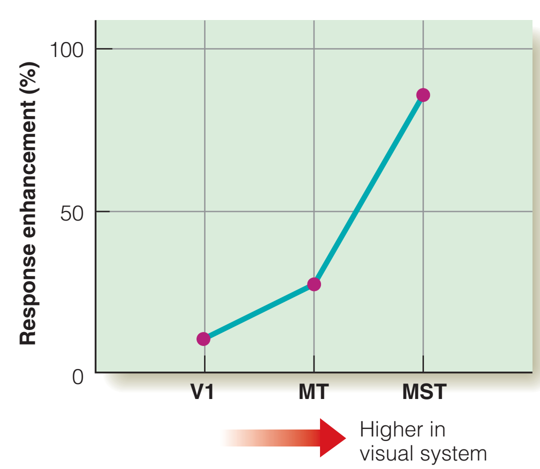


Figure 6.25 ▮ Enhancement of the rate of nerve firing caused by attention for neurons in areas V1, MT, and MST. Area MT is in the dorsal stream, and MST is further "downstream." *(Maunsell, J. H. R. (2004). The role of attention in visual cerebral cortex. In L. M. Chalupa & J. S. Werner (Eds.),* The visual neurosciences *(pp. 1538–1545). Cambridge, MA: MIT Press.)*

(2001), who recorded from neurons in a monkey's inferotemporal (IT) cortex (Figure 4.29) as the monkey was scanning a scene.

In the first part of the experiment, the monkeys were trained to move a lever to the left in response to pictures of some objects and to the right to pictures of other objects. These objects included people, animals, and views of human-made objects such as toys and drinking cups.

After the monkeys had learned the correct response to each picture, Sheinberg and Logothetis found IT neurons that responded to specific pictures. They found that if a neuron responded to a picture when it was presented alone on a blank field, it also responded to the picture when it was placed in an environmental scene. For example, a neuron that fired to a picture of an isolated parrot also fired when the parrot appeared on the roof of a church, as shown in Figure 6.26.

Having shown that the parrot on the roof causes an IT neuron to fire when the parrot is flashed within the neuron's receptive field, the next task was to determine whether the cell would fire when the monkey looked at the parrot while freely scanning the picture. The data below the picture in Figure 6.26 show the monkey's eye movements and when the monkey fixated on the parrot. Immediately after the monkey fixated the parrot, the neuron fired, and shortly after the neuron fired, the monkey moved the lever, indicating that it had identified the parrot. What's important about this result is that the neuron didn't fire when the monkey's gaze came very close to the parrot. It only fired once the monkey had *noticed* the parrot, as indicated by moving the lever.

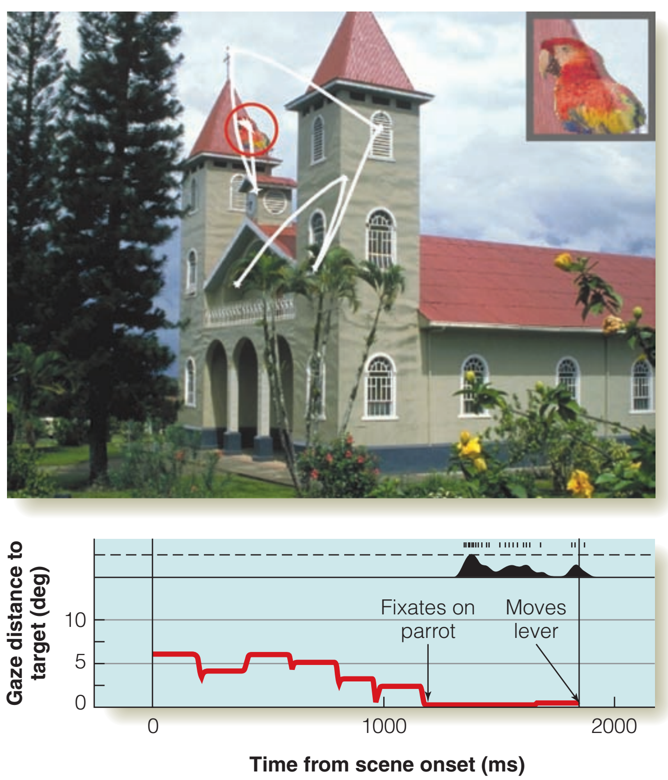


Figure 6.26 Top: scan path as a monkey looked for a target (the parrot on the roof). Just below picture: firing of an IT neuron as the monkey was looking. Bottom: graph showing how far the monkey's gaze was from the parrot. Notice that the neuron begins firing just after the monkey has fixated on the parrot (arrow), and shortly after this the monkey pulls the lever, indicating that it has identified the parrot (vertical line). *(From Sheinberg, D. L., & Logothetis, N. K. (2001). Noticing familiar objects in real world scenes: The role of temporal cortical neurons in natural vision.* Journal of Neuroscience, 21, *1340–1350.)*

Think about what this tells us about the connection between neural firing and perception. A particular scene may contain many different objects, and the brain contains many neurons that respond to those objects. But even though the retina is bombarded with stimuli that could, potentially, cause these neurons to fire, some of these neurons do not fire until a stimulus is *noticed.* This is another example of the fact that firing is not determined only by the image on the retina, but by how behaviorally significant the object is to the observer.

Something to Consider: Attention in Autism

Not only is attention important for detecting objects in the environment, as we have described above; it is also a crucial component of social situations. People pay attention not only to what others are saying, but also to their faces (Gullberg & Holmqvist, 2006) and to where they are looking (Kuhn & Land, 2006; Tatler & Kuhn, 2007), because these things provide information about the other person's thoughts, emotions, and feelings.

The link between attention and perceptions of social interactions becomes especially evident when we consider a situation in which that link is disturbed, as occurs in people with **autism.** Autism is a serious developmental disorder in which one of the major symptoms is the withdrawal of contact from other people. People with autism typically do not make eye contact with others and have difficulty telling what emotions others are experiencing in social situations.

Research has revealed many differences in both behavior and brain processes between autistic and nonautistic people (Grelotti et al., 2002, 2005). Ami Klin and coworkers (2003) note the following paradox: Even though people with autism can often solve reasoning problems that involve social situations, they cannot function when placed in an actual social situation. One possible explanation is differences in the way autistic people observe what is happening. Klin and coworkers (2003) demonstrated this by comparing eye fixations of autistic and nonautistic people as they watched the film *Who's Afraid of Virginia Woolf?*

Figure 6.27 shows fixations on a shot of George Segal's and Sandy Dennis's faces. The shot occurs just after the character in the film played by Richard Burton has smashed a bottle. The nonautistic observers fixated on Segal's eyes

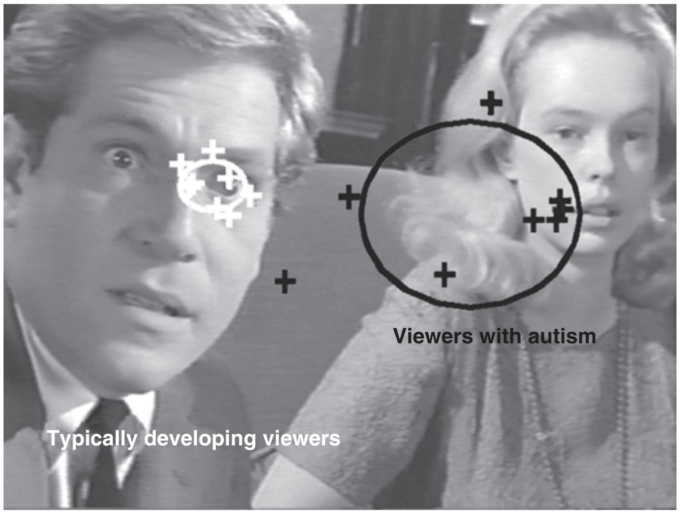


Figure 6.27 ▮ Where people look when viewing this image from the film *Who's Afraid of Virginia Woolf?* Nonautistic viewers: white crosses; autistic viewers: black crosses. *(From "The Enactive Mind, or From Actions to Cognition: Lessons From Autism," by A. Klin, W. Jones, R. Schultz, & F. Wolkmar,* Philosophical Transactions of the Royal Society of London B, *pp. 345–360. Copyright 2003. The Royal Society. Published online.)*

Figure 6.28 ▮ Scan paths for nonautistic viewers (white path) and autistic viewers (black path) in response to the picture and dialogue while viewing this shot from *Who's Afraid of Virginia Woolf? (From "The Enactive Mind, or From Actions to Cognition: Lessons From Autism," by A. Klin, W. Jones, R. Schultz, & F. Wolkmar,* Philosophical Transactions of the Royal Society of London B, *pp. 345–360. Copyright 2003. The Royal Society. Published online.)*

in order to access his emotional reaction, but the autistic observers looked near Sandy Dennis's mouth or off to the side.

Another difference between how autistic and nonautistic observers direct their attention is related to the tendency of nonautistic people to direct their eyes to the place where a person is pointing. Figure 6.28 compares the fixations of a nonautistic person (shown in white) and an autistic person (shown in black). In this scene, Segal's character points to the painting and asks Burton's character, "Who did the painting?" The nonautistic person follows the pointing movement from Segal's finger to the painting and then looks at Burton's face to await a reply. In contrast, the autistic observer looks elsewhere first, than back and forth between the pictures.

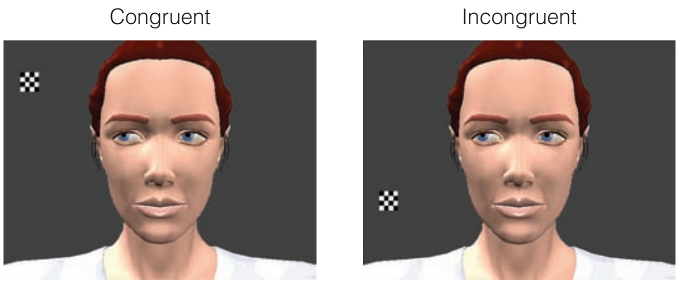
All of these results indicate that because of the way autistic people attend or don't attend to events as they unfold in a social situation, they may perceive the environment differently than normal observers. Autistic people look more at things, whereas nonautistic observers look at other people's actions and especially at their faces and eyes. Autistic observers therefore create a mental representation of a situation that does not include much of the information that nonautistic observers usually use in interacting with others.

Some recent experiments provide clues to physiological differences in attention between autistic and nonautistic people. Kevin Pelphrey and coworkers (2005) measured brain activity in the superior temporal sulcus (STS; see Figure 5.45), an area in the temporal lobe that has been shown to be sensitive to how other people direct their gaze in social situations. For example, the STS is strongly activated when a passerby makes eye contact with a person, but is more weakly activated if the passerby doesn't make eye contact (Pelphrey et al., 2004).

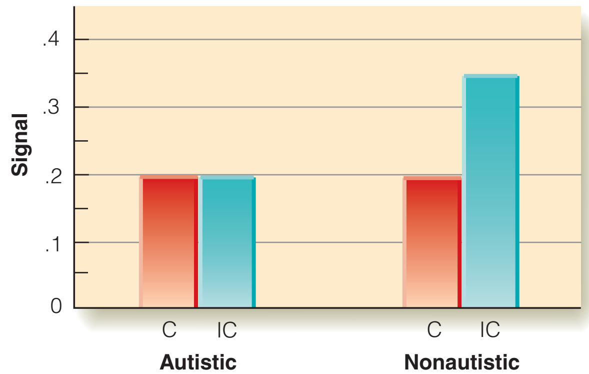
Pelphrey measured STS activity as autistic and nonautistic people watched an animated character's eyes move 1 second after a flashing checkerboard appeared (Figure 6.29a). The character either looked at the checkerboard (congruent condition) or in a direction away from the checkerboard (incongruent condition). To determine whether the observers saw the eye movements, Pelphrey asked his observers to press a button when they saw the character's eyes move. Both autistic and nonautistic observers performed this task with 99 percent accuracy.

But even though both groups of observers saw the character's eyes move, there was a large difference between how the STS responded in the two groups. The STS of the nonautistic observers was activated more for the incongruent situation, but the STS of the autistic observers was activated equally in the congruent and incongruent situations (Figure 6.29b).

What does this result mean? Since both groups saw the character's eyes move, the difference may have to do with how observers *interpreted* what the eye movements meant. Pelphrey suggests that there is a difference in autistic and nonautistic people's ability to read other people's *intentions.* The nonautistic observers expected that the character would look at the checkerboard, and when that didn't happen, this caused a large STS response. Autistic observers, on the other hand, may not have expected the observer to look at the checkerboard, so the STS responded in the same way to both the congruent and incongruent stimuli.



(a)



(b)

Figure 6.29 (a) Observers in Pelphrey's (2005) experiment saw either the congruent condition, in which the animated character looked at the checkerboard 1 second after it appeared, or the incongruent condition, in which the character looked somewhere else 1 second after the checkerboard appeared. (b) Response of the STS in autistic and nonautistic observers to the two conditions: C = congruent; IC = incongruent. *(From Pelphrey, K. A., Morris, J. P., & McCarthy, G. (2005). Neural basis of eye gaze processing deficits in autism.* Brain, 128, *1038–1048. By permission of Oxford University Press.)*

The idea that neural responding may reflect cognitive factors, such as what people *expect* will happen in a particular situation, is something we will encounter again in the next chapter when we consider the connection between perception and how people interact with the environment.

TEST YOURSELF 6.2

1. What evidence is there that attention enhances visual information processing? Why can't we use this evidence to draw conclusions about the connection between attention and perception?
2. Describe the experiment that shows an object's appearance can be changed by attention. What clever feature of this experiment was used to avoid the effect of bias?
3. What is the binding problem? Describe the physiological processes that create this problem.
4. What are the two stages in feature integration theory? What does feature integration theory propose about the role of attention in perception and binding?
5. What evidence links attention and binding? Describe evidence that involves both illusory conjunctions and conjunction search.
6. What is the synchrony explanation for the physiological basis of binding? Has any connection been demonstrated between this explanation and attention?
7. Describe physiological experiments that show that attention enhances neural firing.
8. Describe the experiment that showed that neurons fire when the monkey notices an object.
9. Describe the results of experiments that measured (a) eye movements in autistic and nonautistic observers while they watched a film; (b) the response of the STS to "congruent" and "incongruent" conditions. What can we conclude from these results?

THINK ABOUT IT

1. If salience is determined by characteristics of a scene such as contrast, color, and orientation, why might it be correct to say that paying attention to an object can increase its salience? (p. 136)
2. Art composition books often state that it is possible to arrange elements in a painting in a way that controls both what a person looks at in a picture and the order in which the person looks at things. An example of this would be the statement that when viewing Kroll's *Morning on the Cape* (Figure 6.30), the eye is drawn first to the woman with the books in the foreground, and then to the pregnant woman. But measurements of eye movements show that there are individual differences in the way people look at pictures. For example, E. H. Hess (1965) reported large differences between how men and women looked at the Kroll picture. Try showing this picture, and others, to people as suggested in the figure caption to see if you can observe these individual differences in picture viewing. (p. 135)
3. How is the idea of regularities of the environment that we introduced in Chapter 5 (see page 115) related to the cognitive factors that determine where people look? (p. 136)
4. Can you think of situations from your experience that are similar to the change detection experiments in that you missed seeing an object that became easy to see once you knew it was there? What do you think was behind your initial failure to see this object? (p. 139)
5. The "Something to Consider" section discussed differences between how autistic and nonautistic people

Figure 6.30 Leon Kroll, *Morning on the Cape.* Try showing this picture to a number of people for 1–2 seconds, and ask them what they notice first and what else they see. You can't determine eye scan patterns using this method, but you may gain some insight into differences in the way different people look at pictures.

direct their attention. Do you think differences in directing attention may also occur in nonautistic people? Can you think of situations in which you and another person perceived the same scene or event differently? (p. 148)

IF YOU WANT TO KNOW MORE

1. *Dividing attention.* Our ability to divide our attention among different tasks depends on the nature of the task and also on how well we have practiced specific tasks. The following two references describe (1) the idea that task difficulty determines our ability to divide our attention and (2) the finding that people who play video games may increase their ability to divide their attention among different tasks. (p. 134)

   Green, G. S., & Bavelier, D. (2003). Action video game modifies visual selective attention. *Nature, 423,* 534–537.

   Lavie, N. (1995). Perceptual load as a necessary condition for selective attention. *Journal of Experimental Psychology: Human Perception and Performance, 21,* 451–486.

2. *Eye movements.* The role of eye movements in determining attention is often studied by measuring the sequence of fixations that a person makes when freely viewing a picture. However, another important variable is how long a person looks at particular areas of a picture. Factors that determine the length of fixation may not be the same as those that determine the sequence of fixations. (p. 135)

   Henderson, J. M. (2003). Human gaze control during real-world scene perception. *Trends in Cognitive Sciences, 7,* 498–503.

3. *When does selection occur in selective attention?* A classic controversy in the field of attention is whether selective attention involves "early selection" or "late selection." Researchers in the "early selection" camp hold that when many messages are present, people select one to attend to based on physical characteristics of the message, such as a person's voice. Researchers in the "late selection" camp state that people don't select which message to attend until they have analyzed the meaning of the various messages that are present. (p. 135)

   Broadbent, D. E. (1958). *Perception and communication.* London: Pergamon.

   Luck, S. J., & Vecera, S. P. (2002). Attention. In H. Pashler & S. Yantis (Eds.), *Stevens' handbook of experimental psychology* (3rd ed., pp. 235–286). New York: Wiley.

   Treisman, A. M. (1964). Selective attention in man. *British Medical Bulletin, 20,* 12–16.

4. *Eye movements and reward systems.* The reward value of an element in a scene may help determine where people look. This idea is supported by evidence that looking at certain objects activates reward areas in the brain. (p. 135)

   Yue, X., Vessel, E. A., & Biederman, I. (2007). The neural basis of scene preferences. *Neuroreport, 18,* 525–529.

5. *Features and visual search.* Visual search has been used not only to study binding, as described in this chapter, but also to study how the match or mismatch between features in the target and the distractors can influence the ability to find the target. When a target has features that differ from those of the distractors, the target "pops out" and so is perceived immediately. However, when the target shares features with the

distractors, search takes longer. You can demonstrate this for yourself in Virtual Lab 12: Feature Analysis. (p. 144) VL 12

Treisman, A. (1986). Features and objects in visual processing. *Scientific American, 255,* 114B–125B.

Treisman, A. (1998). The perception of features and objects. In R. D. Wright (Ed.), *Visual attention* (pp. 26–54). New York: Oxford University Press.

6. *Emotion and attention.* There is evidence that emotion can affect attention in a number of ways, including the ability to detect stimuli and the appearance of objects. (p. 142)

Phelps, E. A., Ling, S., & Carrasco, M. (2006). Emotion facilitates perception and potentiates the perceptual benefits of attention. *Psychological Science, 17,* 292–299.

KEY TERMS

Attention (p. 134)
Autism (p. 148)
Balint's syndrome (p. 145)
Binding (p. 143)
Binding problem (p. 144)
Change blindness (p. 140)
Conjunction search (p. 146)
Divided attention (p. 134)
Feature integration theory (p. 144)
Feature search (p. 145)
Fixation (p. 135)
Focused attention stage (p. 144)
Illusory conjunction (p. 144)
Inattentional blindness (p. 138)
Preattentive stage (p. 144)
Precueing (p. 141)
Saccade (p. 135)
Saliency map (p. 136)
Selective attention (p. 134)
Stimulus salience (p. 135)
Synchrony (p. 146)
Synchrony hypothesis (p. 146)
Visual search (p. 145)

MEDIA RESOURCES

The *Sensation and Perception* Book Companion Website

www.cengage.com/psychology/goldstein

See the companion website for flashcards, practice quiz questions, Internet links, updates, critical thinking exercises, discussion forums, games, and more!

CengageNOW

www.cengage.com/cengagenow

Go to this site for the link to CengageNOW, your one-stop shop. Take a pre-test for this chapter, and CengageNOW will generate a personalized study plan based on your test results. The study plan will identify the topics you need to review and direct you to online resources to help you master those topics. You can then take a post-test to help you determine the concepts you have mastered and what you will still need to work on.

Virtual Lab

Your Virtual Lab is designed to help you get the most out of this course. The Virtual Lab icons direct you to specific media demonstrations and experiments designed to help you visualize what you are reading about. The number beside each icon indicates the number of the media element you can access through your CD-ROM, CengageNOW, or WebTutor resource.

The following lab exercises are related to material in this chapter:

1. *Eye Movements While Viewing a Scene* Records of a person's fixations while viewing a picture of a scene. (Courtesy of John Henderson.)
2. *Task-Driven Eye Movements* Records of a head-mounted eye movement camera that show eye movements as a person makes a peanut butter and jelly sandwich. (Courtesy of Mary Hayhoe.)
3. *Perception Without Focused Attention* Some stimuli from Reddy's (2007) experiment in which she tested observers' ability to identify stimuli presented rapidly off to the side of the focus of attention. (Courtesy of Leila Reddy.)
4. *Inattentional Blindness Stimuli* The sequence of stimuli presented in an inattentional blindness experiment.
5. *Change Detection: Gradual Changes* Three images that test your ability to detect changes that happen slowly.
6. *Change Detection: Airplane* A test of your ability to determine the difference between two images that are flashed rapidly, separated by a blank field. (Courtesy of Ronald Rensink.)
7. *Change Detection: Farm* (Courtesy of Ronald Rensink.)
8. *Change Blindness: Harborside* (Courtesy of Ronald Rensink.)
9. *Change Detection: Money* (Courtesy of Ronald Rensink.)
10. *Change Detection: Sailboats* (Courtesy of Ronald Rensink.)
11. *Change Detection: Tourists* (Courtesy of Ronald Rensink.)
12. *Feature Analysis* A number of visual search experiments in which you can determine the function relating reaction time and number of distractors for a number of different types of targets and distractors.