SOME QUESTIONS WE WILL CONSIDER

- How do "pictures in your head" that you create by imagining an object compare to the experience you have when you see the actual object? (282)
- What happens in your brain when you create visual images with your eyes closed? (285)
- How does damage to the brain affect the ability to form visual images? (288)
- How can we use visual imagery to improve memory? (291)

Let's return for a moment to Raphael, who, at the beginning of Chapter 1, was walking across campus talking to Susan on his cell phone (see **Figure 1.1**, page 4, for a retrieval cue!). One of Raphael's problems is that he has left Susan's book at home; as he realizes this, he thinks, "I can see it sitting there on my desk, where I left it." Raphael's ability to "see" Susan's book, even though it is not present, is an example of **visual imagery**—seeing in the absence of a visual stimulus.

Another example of visual imagery is my experience of being able to visually remember seeing the Pacific Ocean after cresting a mountain in California (page 162). This example was used to introduce the idea that mental time travel is a characteristic of episodic memory. Although mental time travel does not have to involve visual imagery, it often does, as it did for my "seeing what was on the other side of the mountain" experience. But imagery doesn't have to involve such drama! Consider, for example, the following demonstration.

DEMONSTRATION
EXPERIENCING IMAGERY

Answer the following questions:

- How many windows are there in front of the house or apartment where you live?
- How is the furniture arranged in your bedroom?
- Are an elephant's ears rounded or pointy?
- Is the green of grass darker or lighter than the green of a pine tree?

How did you go about answering these questions? Many people report that they experience visual images when answering questions such as these. On a more practical level, they might create images to help pack suitcases in the trunk of their car or rearrange furniture in the living room (Hegarty, 2010).

Mental imagery, the ability to recreate the sensory world in the absence of physical stimuli, also occurs in senses other than vision. People have the ability to imagine tastes, smells, and tactile experiences. Most people can imagine melodies of familiar songs in their head, so it is not surprising that musicians often report strong auditory imagery and that the ability to imagine melodies has played an important role in musical composition. Paul McCartney says that the song "Yesterday" came to him as a mental image when he woke up with the tune in his head. Another example of auditory imagery is orchestra conductors' using a technique called the "inner audition" to practice without their orchestras by imagining a musical score in their minds. When they do this, they imagine not only the sounds of the various instruments but also their locations relative to the podium.

Just as auditory imagery has played an important role in the creative process of music, visual imagery has resulted in both scientific insights and practical applications. One of the most famous accounts of how visual imagery led to scientific discovery is the story related by the 19th-century German chemist Friedrich August Kekule. Kekule said that the structure of benzene came to him in a dream in which he saw a writhing chain that formed a circle that resembled a snake, with its head swallowing its tail. This visual image gave Kekule the insight that the carbon atoms that make up the benzene molecule are arranged in a ring.

A more recent example of visual imagery leading to scientific discovery is Albert Einstein's description of how he developed the theory of relativity by imagining himself traveling beside a beam of light (Intons-Peterson, 1993). On a more athletic level, many competitors at the Olympics use mental imagery to visualize downhill ski runs, snowboarding moves, bobsled turns, and speedskating races (Clarey, 2014).

One message of these examples is that imagery provides a way of thinking that adds another dimension to the verbal techniques usually associated with thinking. But what is most important about imagery is that it is associated not just with discoveries by famous people but also with most people's everyday experience. In this chapter we will focus on visual imagery, because most of the research on imagery has been on this type of imagery. We will describe the basic characteristics of visual imagery and how it relates to other cognitive processes such as thinking, memory, and perception. This connection between imagery and cognition in general is an important theme in the history of psychology, beginning in the early days of scientific psychology in the 19th century.

Imagery in the History of Psychology

We can trace the history of imagery back to the first laboratory of psychology, founded by Wilhelm Wundt (see Chapter 1, page 7).

EARLY IDEAS ABOUT IMAGERY

Wundt proposed that images were one of the three basic elements of consciousness, along with sensations and feelings. He also proposed that because images accompany thought, studying images was a way of studying thinking. This idea of a link between imagery and thinking gave rise to the **imageless thought debate**, with some psychologists taking up Aristotle's idea that "thought is impossible without an image" and others contending that thinking can occur without images.

Evidence supporting the idea that imagery was not required for thinking was Francis Galton's (1883) observation that people who had great difficulty forming visual images were still quite capable of thinking (also see Richardson, 1994, for more modern accounts of imagery differences between people). Other arguments both for and against the idea that images are necessary for thinking were proposed in the late 1800s and early 1900s, but these arguments and counterarguments ended when behaviorism toppled imagery from its central place in psychology (Watson, 1913; see Chapter 1, page 9). The behaviorists branded the study of imagery as unproductive because visual images are invisible to everyone except the person experiencing them. The founder of behaviorism, John Watson, described images as "unproven" and "mythological" (1928), and therefore not worthy of study. The dominance of behaviorism from the 1920s through the 1950s pushed the study of imagery out of mainstream psychology. However, this situation changed when the study of cognition was reborn in the 1950s.

IMAGERY AND THE COGNITIVE REVOLUTION

The history of cognitive psychology that we described in Chapter 1 recounts events in the 1950s and 1960s that came to be known as the cognitive revolution. One of the keys to the success of this "revolution" was that cognitive psychologists developed ways to measure behavior that could be used to infer cognitive processes. One example of a method that linked behavior and cognition is Alan Paivio's (1963) work on memory. Paivio showed that it was easier to remember concrete nouns, like *truck* or *tree*, that can be imaged, than it is to remember abstract nouns, like *truth* or *justice*, that are difficult to image. One technique Paivio used was *paired-associate learning.*

METHOD

PAIRED-ASSOCIATE LEARNING

In a **paired-associate learning** experiment, subjects are presented with pairs of words, like *boat–hat* or *car–house*, during a study period. They are then presented, during the test period, with the first word from each pair. Their task is to recall the word that was paired with it during the study period. Thus, if they were presented with the word *boat*, the correct response would be *hat*.

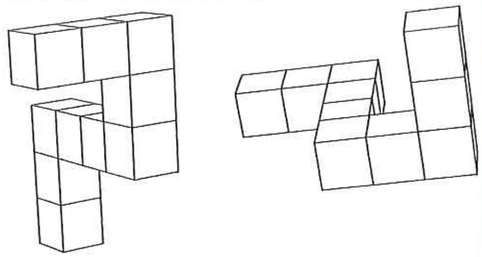

Figure 10.1 Stimuli for Shepard and Metzler's (1971) mental rotation experiment. *(Source: From R. N. Shepard & J. Metzler, Mental rotation of three-dimensional objects,* Science, *171, 701–703, Figures 1A & B, 1971.)*

As noted, Paivio (1963, 1965) found that memory for pairs of concrete nouns is much better than memory for pairs of abstract nouns. To explain this result, Paivio proposed the **conceptual peg hypothesis**. According to this hypothesis, concrete nouns create images that other words can "hang onto." For example, if presenting the pair *boat–hat* creates an image of a boat, then presenting the word *boat* later will bring back the boat image, which provides a number of places on which subjects can place the hat in their mind (see Paivio, 2006, for an updating of his ideas about memory).

Whereas Paivio inferred cognitive processes by measuring memory, Roger Shepard and Jacqueline Metzler (1971) inferred cognitive processes by using **mental chronometry**, determining the amount of time needed to carry out various cognitive tasks. In Shepard and Metzler's experiment, which we described in Chapter 5 (see page 137), subjects saw pictures like the ones in **Figure 10.1**. Their task was to indicate, as rapidly as possible, whether the two pictures were of the same object or of different objects. This experiment showed that the time it took to decide that two views were of the same object was directly related to how different the angles were between the two views (see **Figure 5.15**, page 138). This result was interpreted as showing that subjects were mentally rotating one of the views to see whether it matched the other one.

What was important about this experiment was that it was one of the first to apply quantitative methods to the study of imagery and to suggest that imagery and perception may share the same mechanisms. (References to "mechanisms" include both mental mechanisms, such as ways of manipulating perceptual and mental images in the mind, and brain mechanisms, such as which structures are involved in creating perceptual and mental images.)

We will now describe research that illustrates similarities between imagery and perception, and also the possibility that there is a basic difference between how imagery and perception are represented in the mind. As we will see, these comparisons of imagery and perception have involved a large number of behavioral and physiological experiments, which demonstrate both similarities and differences between imagery and perception.

Imagery and Perception: Do They Share the Same Mechanisms?

The idea that imagery and perception may share the same mechanisms is based on the observation that although mental images differ from perception in that they are not as vivid or long lasting, imagery shares many properties with perception. Shepard and Metzler's results showed that mental and perceptual images both involve spatial representation of the stimulus. That is, the spatial experience for both imagery and perception matches the layout of the actual stimulus. This idea, that there is a spatial correspondence between imagery and perception, is supported by a number of experiments by Stephen Kosslyn involving a task called **mental scanning**, in which subjects create mental images and then scan them in their minds.

KOSSLYN'S MENTAL SCANNING EXPERIMENTS

Stephen Kosslyn has done enough research on imagery to fill three books (Kosslyn, 1980, 1994; Kosslyn et al., 2006), and he has proposed some influential theories of imagery based on parallels between imagery and perception. In one of his early experiments, Kosslyn (1973) asked subjects to memorize a picture of an object, such as the boat in **Figure 10.2**, and then to create an image of that object in their mind and to focus on one part of the boat, such as the anchor. They were then asked to look for another part of the boat, such as the motor, and to press the "true" button when they found this part or the "false" button when they couldn't find it.

Kosslyn reasoned that if imagery, like perception, is spatial, then it should take longer for subjects to find parts that are located farther from the initial point of focus because they would be scanning across the image of the object. This is actually what happened, and Kosslyn took this as evidence for the spatial nature of imagery. But, as often happens in science, another researcher proposed a different explanation. Glen Lea (1975) proposed that as subjects scanned, they may have encountered other interesting parts, such as the cabin, and this distraction may have increased their reaction time.

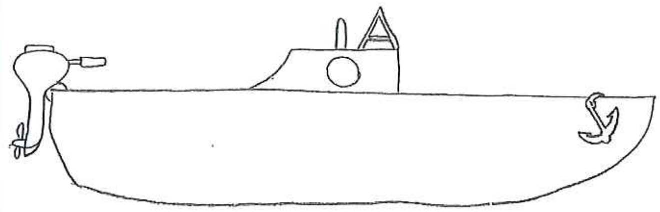

Figure 10.2 Stimulus for Kosslyn's (1973) image-scanning experiment. *(Source: S. M. Kosslyn, Scanning visual images: Some structural Implications,* Perception & Psychophysics, 14, *90–94, Figure 1. Copyright © 1973 The Psychonomic Society Publications. Reproduced with permission.)*

To answer this concern, Kosslyn and coworkers (1978) did another scanning experiment, this time asking subjects to scan between two places on a map. Before reading about Kosslyn's experiment, try the following demonstration.

METHOD/DEMONSTRATION
MENTAL SCANNING

Imagine a map of your state that includes three locations: the place where you live, a town that is far away, and another town that is closer but does not fall on a straight line connecting your location and the far town. For example, for my state, I imagine Pittsburgh, the place where I am now; Philadelphia, all the way across the state (contrary to some people's idea, Pittsburgh is not a suburb of Philadelphia!); and Erie, which is closer than Philadelphia but not in the same direction (**Figure 10.3**).

Your task is to create a mental image of your state and, starting at your location, to form an image of a black speck moving along a straight line between your location and the closer town. Be aware of about how long it took to arrive at this town. Then repeat the same procedure for the far town, again noting about how long it took to arrive.

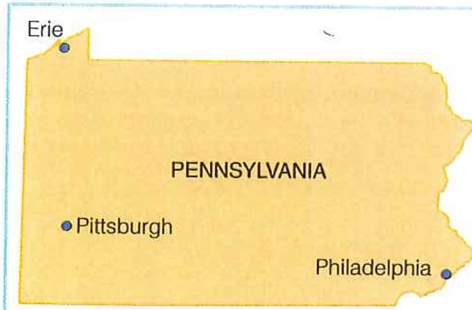

Figure 10.3 Example of a state map for Mental Scanning method/demonstration. Use your own state for this method/demonstration. © Cengage Learning

Kosslyn's subjects used the same procedure as you did for the demonstration but were told to imagine an island, like the one in **Figure 10.4a**, that contained seven different locations. By having subjects scan between every possible pair of locations (a total of 21 trips), Kosslyn determined the relationship between reaction time and distance shown in **Figure 10.4b**. Just as in the boat experiment, it took longer to scan between greater distances on the image, a result that supports the idea that visual imagery is spatial in nature. As convincing as Kosslyn's results were, however, Zenon Pylyshyn (1973) proposed another explanation, which started what has been called the **imagery debate**—a debate about whether imagery is based on spatial mechanisms, such as those involved in perception, or on mechanisms related to language, called *propositional mechanisms.*

THE IMAGERY DEBATE: IS IMAGERY SPATIAL OR PROPOSITIONAL?

Much of the research we have described so far in this book is about determining the nature of the mental representations that lie behind different cognitive experiences. For example, when we considered short-term memory (STM) in Chapter 5, we presented evidence that information in STM is often represented in auditory form, as when you rehearse a telephone number you have just looked up in a phone book or online.

Kosslyn interpreted the results of his research on imagery as supporting the idea that the mechanism responsible for imagery involves a **spatial representation**—a representation in which different parts of an image can be described as corresponding to specific locations in space. But Pylyshyn (1973) disagreed, saying that just because we *experience*

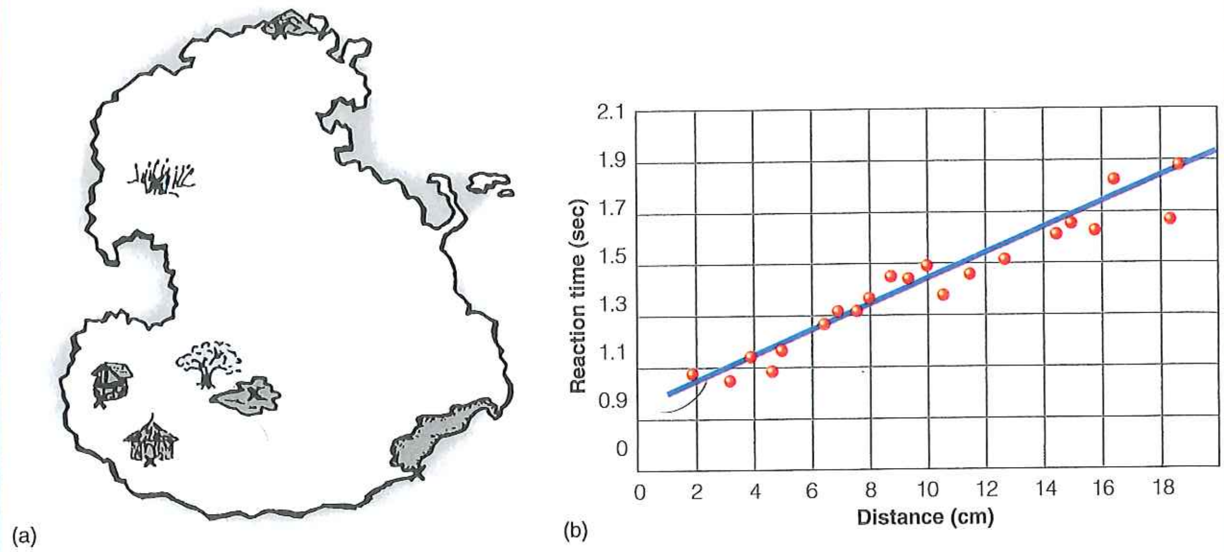

Figure 10.4 (a) Island used in Kosslyn et al.'s (1978) image-scanning experiment. Subjects mentally traveled between various locations on the island. (b) Results of the island experiment. *(Source: S. M. Kosslyn, T. Ball, & B. J. Reiser, Visual images preserve metric spatial information: Evidence from studies of image scanning,* Journal of Experimental Psychology: Human Perception and Performance, *4, no. 1, 47–60, 1978.)*

imagery as spatial, that doesn't mean that the *underlying representation* is spatial. After all, one thing that is clear from research in cognitive psychology is that we often aren't aware of what is going on in our mind. The spatial experience of mental images, argues Pylyshyn, is an **epiphenomenon**—something that accompanies the real mechanism but is not actually part of the mechanism.

An example of an epiphenomenon is lights flashing as a mainframe computer carries out its calculations. The lights may indicate that *something* is going on inside the computer, but they don't necessarily tell us what is actually happening. In fact, if all of the lightbulbs blew out, the computer would continue operating just as before. Mental images, according to Pylyshyn, are similar—they indicate that *something* is happening in the mind, but don't tell us *how* it is happening.

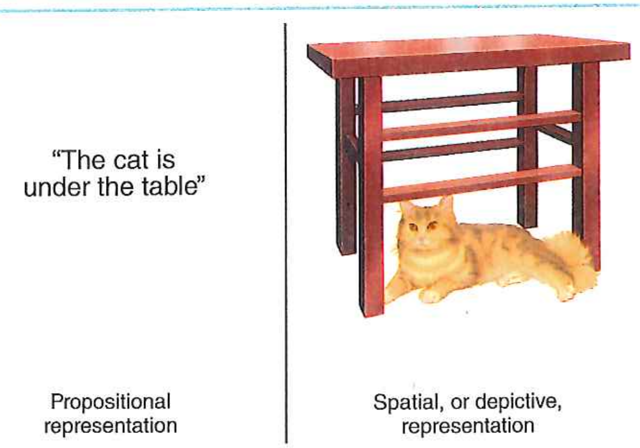

Figure 10.5 Propositional and spatial, or depictive, representations of "The cat is under the table."

Pylyshyn proposed that the mechanism underlying imagery is not spatial but propositional. A **propositional representation** is one in which relationships can be represented by abstract symbols, such as an equation, or a statement such as "The cat is under the table." In contrast, a spatial representation would involve a spatial layout showing the cat and the table that could be represented in a picture (**Figure 10.5**). Representations that are like realistic pictures of an object, so that parts of the representation correspond to parts of the object, are called **depictive representations**.

We can understand the propositional approach better by returning to the depictive representation of Kosslyn's boat in **Figure 10.2**. **Figure 10.6** shows how the visual appearance of this boat can be represented propositionally. The words indicate parts of the boat, the length of the lines indicate the distances between the parts, and the words in parentheses indicate the spatial relations between the parts. A representation such as this would predict that when starting at the motor, it should take longer to scan and find the anchor than to find the porthole because it is necessary to travel across three links to get

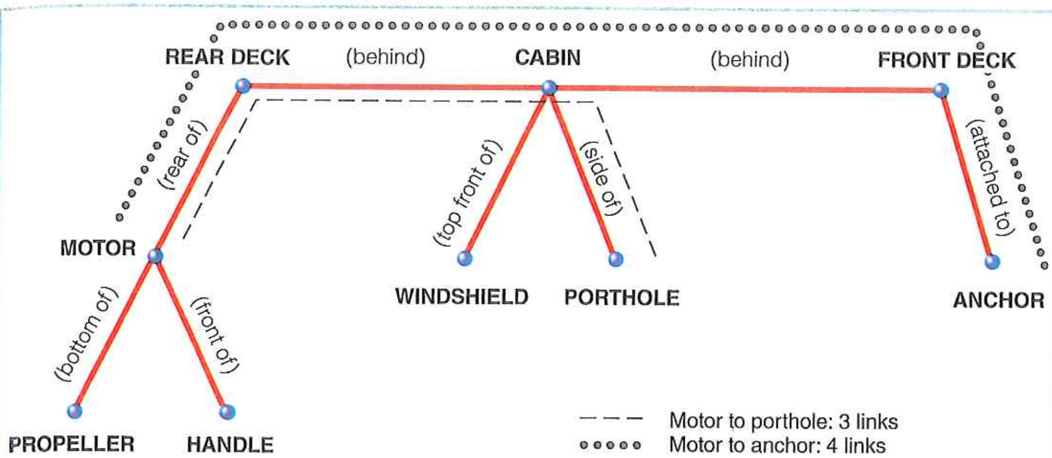

Figure 10.6 How the visual appearance of the boat in Figure 10.2 can be represented propositionally. Paths between motor and porthole (dashed line) and motor and anchor (dotted line) indicate the number of nodes that would be traversed between these parts of the boat. *(Source: Reprinted from S. M. Kosslyn, Mental imagery, in S. M. Kosslyn & D. N. Osherson,* An invitation to cognitive science, *2nd ed., vol. 2:* Visual cognition, *pp. 267–296, Figure 7.6. Copyright © 1995 MIT Press.)*

to the porthole (dashed line) and four links to get to the anchor (dotted line). This kind of explanation proposes that imagery operates in a way similar to the semantic networks we described in Chapter 9 (see page 256).

In addition to suggesting that Kosslyn's results can be explained in terms of propositional representations, Pylyshyn also suggested that one reason that scanning time increases as the distance between two points on an image increases is that subjects are responding to Kosslyn's tasks based on what they know about what usually happens when they are looking at a real scene. According to Pylyshyn (2003), "When asked to imagine something, people ask themselves what it would look like to see it, and they then simulate as many aspects of this staged event as they can" (p. 113). People know that in the real world it takes longer to travel longer distances, just as I know it takes longer to drive from Pittsburgh to Philadelphia than to Erie, so, Pylyshyn suggests, they simulate this result in Kosslyn's experiment. This is called the **tacit knowledge explanation** because it states that subjects unconsciously use knowledge about the world in making their judgments.

Although Pylyshyn was in the minority (most researchers accepted the spatial representation explanation of visual imagery), his criticisms couldn't be ignored, and researchers from the "spatial" camp proceeded to gather more evidence. For example, to counter the tacit knowledge explanation of Kosslyn's mental scanning results, Ronald Finke and Stephen Pinker (1982) briefly presented a four-dot display, like the one in **Figure 10.7a**, and then, after a 2-second delay, presented an arrow, as in **Figure 10.7b**. The subjects' task was to indicate whether the arrow was pointing to any of the dots they had just seen.

Although the subjects were not told to use imagery or to scan outward from the arrow, they took longer to respond for greater distances between the arrow and the dot. In fact, the results look very similar to the results of other scanning experiments. Finke and Pinker argue that because their subjects wouldn't have had time to memorize the distances between the arrow and the dot before making their judgments, it is unlikely that they used tacit knowledge about how long it should take to get from one point to another.

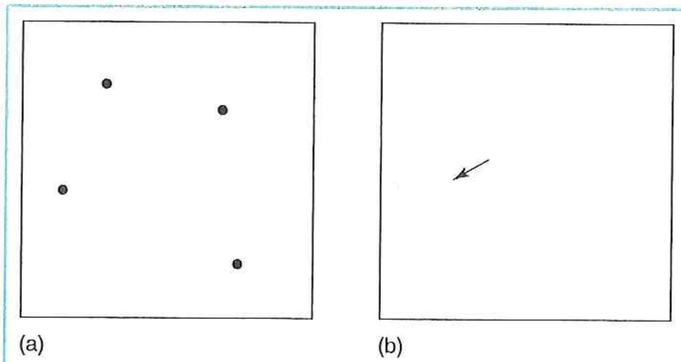

Figure 10.7 Stimuli for Finke and Pinker's (1982) experiment. The display in (a) was presented first, followed, after a 2-second delay, by the arrow in (b). The subjects' task was to determine whether the arrow pointed to any of the dots that had been presented in the first display. *(Source: From R. A. Finke & S. Pinker, Spontaneous imagery scanning in mental extrapolation,* Journal of Experimental Psychology: Learning, Memory and Cognition, *8, 2, 142–147, Figure 1, 1982.)*

We've discussed both the spatial and the propositional approaches to imagery because these two explanations provide an excellent example of how data can be interpreted in different ways. Pylyshyn's criticisms stimulated a large number of experiments that have taught us a great deal about the nature of visual imagery (also see Intons-Peterson, 1983). The weight of the evidence supports the idea that imagery is served by a spatial mechanism and that it shares mechanisms with perception. We will now look at additional evidence that supports the idea of spatial representation.

COMPARING IMAGERY AND PERCEPTION

We begin by describing another experiment by Kosslyn. This one looks at how imagery is affected by the size of an object in a person's visual field.

SIZE IN THE VISUAL FIELD If you observe an automobile from far away, it fills only a portion of your visual field, and it is difficult to see small details such as the door handle. As you move closer, it fills more of your visual field, and you can perceive details like the door handle more easily (**Figure 10.8**). With these observations about perception in mind, Kosslyn wondered whether this relationship between viewing distance and the ability to perceive details also occurs for mental images.

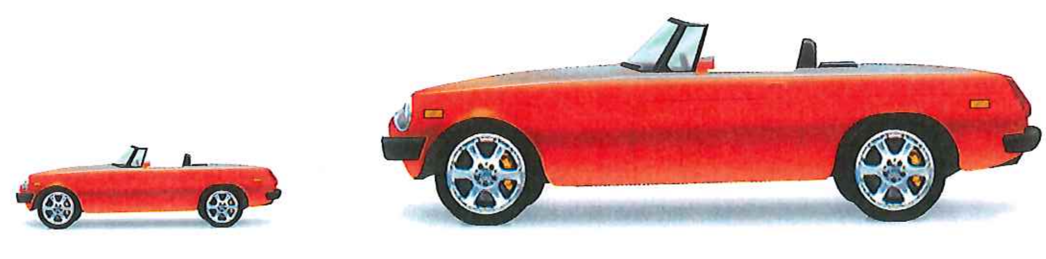

Figure 10.8 Moving closer to an object, such as this car, has two effects: (1) The object fills more of your visual field, and (2) details are easier to see.

To answer this question, Kosslyn (1978) asked subjects to imagine two animals, such as an elephant and a rabbit, next to each other and to imagine that they were standing close enough to the larger animal that it filled most of their visual field (**Figure 10.9a**). He then posed questions such as "Does the rabbit have whiskers?" and asked his subjects to find that part of the animal in their mental image and to answer as quickly as possible. When he repeated this procedure but told subjects to imagine a rabbit and a fly next to each other, subjects created larger images of the rabbit, as shown in **Figure 10.9b**. The result of these experiments, shown alongside the pictures, was that subjects answered questions about the rabbit more rapidly when it filled more of the visual field.

In addition to asking subjects to respond to details in visual images, Kosslyn also asked them to do a **mental walk task**, in which they were to imagine that they were walking toward their mental image of an animal. Their task was to estimate how far away they were from the animal when they began to experience "overflow"—when the image filled the visual field or when its edges started becoming fuzzy. The result was that subjects had to move closer for small animals (less than a foot away for a mouse) than for larger animals (about 11 feet away for an elephant), just as they would have to do if they were walking toward actual animals. This result provides further evidence for the idea that images are spatial, just like perception.

INTERACTIONS OF IMAGERY AND PERCEPTION Another way to demonstrate connections between imagery and perception is to show that they interact with one another. The basic rationale behind this approach is that if imagery affects perception, or perception affects imagery, this means that imagery and perception both have access to the same mechanisms.

The classic demonstration of interaction between perception and imagery dates back to 1910, when Cheves Perky did the experiment pictured in **Figure 10.10**. Perky asked her subjects to "project" visual images of common objects onto a screen, and then to describe these images. Unbeknownst to the subjects, Perky was back-projecting a very dim image of this object onto the screen. Thus, when subjects were asked to create an image of a banana, Perky projected a dim image of a banana onto the screen. Interestingly, the subjects' descriptions of their images matched the images that Perky was projecting. For example, they described the banana as being oriented vertically, just as was the projected image. Even more interesting, not one of Perky's 24 subjects noticed that there was an actual picture on the screen. They had apparently mistaken an actual picture for a mental image.

Modern researchers have replicated Perky's result (see Craver-Lemley & Reeves, 1992; Segal & Fusella, 1970) and have demonstrated interactions between perception and imagery in a number of other ways. Martha Farah (1985) instructed her subjects to imagine either the letter *H* or the letter *T* on a screen (**Figure 10.11a**). Once they had formed a clear image on the screen, they pressed a button that caused two squares to flash, one after the other (**Figure 10.11b**). One of the squares contained a target letter, which was either an *H* or a *T*. The subjects' task was to indicate whether the letter was in the first square or the second one. The results, shown in **Figure 10.11c**, indicate that the target letter was detected more accurately when the subject had been imagining the same letter rather than the different letter. Farah interpreted this result as showing that perception and imagery share mechanisms; later experiments that have also shown that imagery can affect perception have come to the same conclusion (Kosslyn & Thompson, 2000; Pearson et al., 2008).

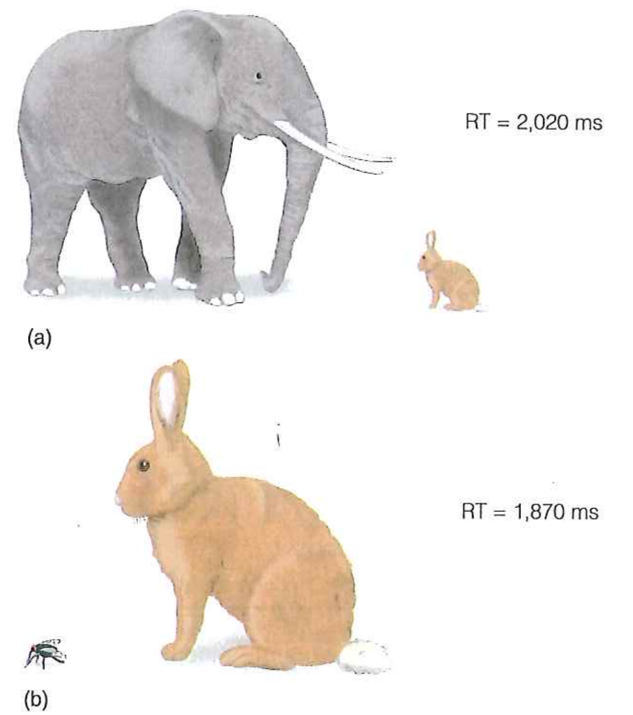

Figure 10.9 These pictures represent images that Kosslyn's (1978) subjects created, which filled different portions of their visual field. (a) Imagine elephant and rabbit, so elephant fills the field. (b) Imagine rabbit and fly, so rabbit fills the field. Reaction times indicate how long it took subjects to answer questions about the rabbit.

IS THERE A WAY TO RESOLVE THE IMAGERY DEBATE?

You might think, from the evidence of parallels between imagery and perception and of interactions between them, that the imagery debate would have been settled once and for all in favor of the spatial explanation. But John Anderson (1978) warned that despite this evidence, we still can't rule out the propositional explanation, and Martha Farah (1988) pointed out that it is difficult to rule out Pylyshyn's tacit knowledge explanation just on the basis of the results of behavioral experiments like the ones we have been describing. She argued that it is always possible that subjects can be influenced by their past experiences with perception, so they could unknowingly be simulating perceptual responses in imagery experiments. For example, in the mental walk experiments, in which subjects were supposed to be imagining that they were walking toward their mental image of an animal, subjects could be using their knowledge from prior experience in perceiving animals to conclude that they would have to be closer to a mouse than to an elephant before these animals would fill up their field of view.

But Farah suggested a way out of this problem: Instead of relying solely on behavioral experiments, we should investigate

Figure 10.10 Subject in Perky's (1910) experiment. Unbeknownst to the subjects, Perky was projecting dim images onto the screen.

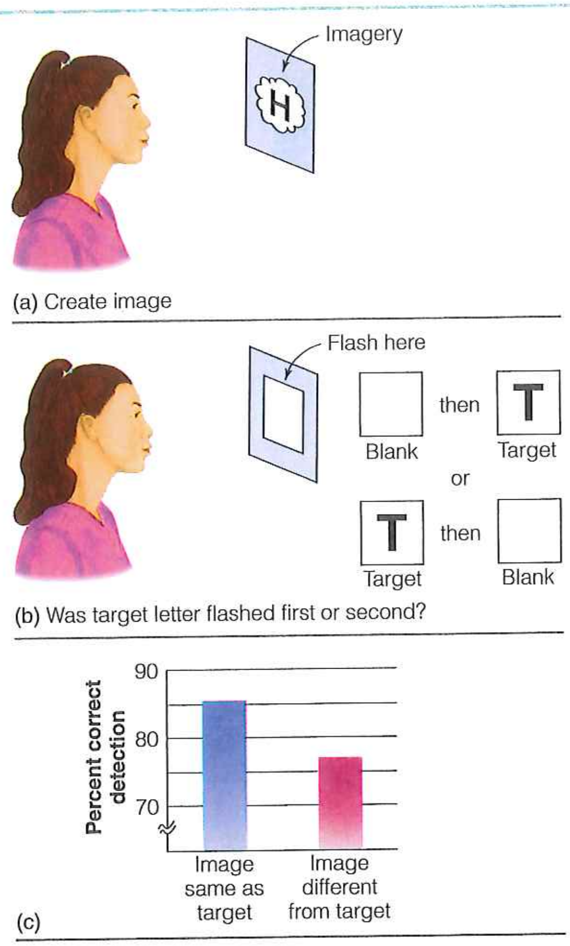

Figure 10.11 Procedure for Farah's (1985) letter visualization experiment. (a) The subject visualizes *H* or *T* on the screen. (b) Then two squares flash, one after the other, on the same screen. As shown on the right, the target letter can be in the first square or in the second one. The subjects' task is to determine whether the test letter was flashed in the first or in the second square. (c) Results showing that accuracy was higher when the letter in (b) was the same as the one that had been imagined in (a). *(Source: Based on M. J. Farah, Psychophysical evidence for a shared representational medium for mental images and percepts,* Journal of Experimental Psychology: General, 114, *91–103, 1985.)*

how the brain responds to visual imagery. The reason Farah was able to make this proposal was that by the 1980s, evidence about the physiology of imagery was becoming available from neuropsychology—the study of patients with brain damage—and from electrophysiological measurements. In addition, beginning in the 1990s, brain imaging experiments provided additional data regarding the physiology of imagery. We will describe measurements of the brain's response to imagery in the next section.

TEST YOURSELF 10.1

1. Is imagery just a "laboratory phenomenon," or does it occur in real life?
2. Make a list of the important events in the history of the study of imagery in psychology, from the imageless thought debate of the 1800s to the studies of imagery that occurred early in the cognitive revolution in the 1960s and 1970s.
3. How did Kosslyn use the technique of mental scanning (in the boat and island experiments) to demonstrate similarities between perception and imagery? Why were Kosslyn's experiments criticized, and how did Kosslyn answer Pylyshyn's criticism with additional experiments?
4. Describe the spatial (or depictive) and propositional explanations of the mechanism underlying imagery. How can the propositional explanation interpret the results of Kosslyn's boat and island image-scanning experiments?
5. What is the tacit knowledge explanation of imagery experiments? What experiment was done to counter this explanation?
6. How have experiments demonstrated interactions between imagery and perception? What additional evidence is needed to help settle the imagery debate, according to Farah?

Imagery and the Brain

As we look at a number of types of physiological experiments, we will see that a great deal of evidence points to a connection between imagery and perception, but the overlap is not perfect. We begin by looking at the results of research that has measured the brain's response to imagery and will then consider how brain damage affects the ability to form visual images.

IMAGERY NEURONS IN THE BRAIN

Studies in which activity is recorded from single neurons in humans are rare (see Method: Recording from Single Neurons in Humans, Chapter 3, page 79). But Gabriel Kreiman and coworkers (2000) were able to study patients who had electrodes implanted in various areas in their medial temporal lobe, which includes the hippocampus and the amygdala (see **Figure 5.22**, page 142), in order to determine the source of severe epileptic seizures that could not be controlled by medication.

In this study, Kreiman and coworkers found neurons that responded to some objects but not to others. For example, the records in **Figure 10.12a** show the response of a neuron that responded to a picture of a baseball but did not respond to a picture of a face. Notice in **Figure 10.12b** that this neuron fired in the same way when the person closed his or her eyes and *imagined* a baseball (good firing) or a face (no firing). Kreiman calls these neurons **imagery neurons**.

Kreiman's discovery of imagery neurons is important, both because it demonstrates a possible physiological mechanism for imagery and because these neurons respond in the same way to *perceiving* an object and to *imagining* it, thereby supporting the idea of a close relation between perception and imagery. However, most research on the physiology of imagery has involved large areas of the brain. Beginning in the early 1990s, researchers began using brain imaging to measure brain activity as subjects were perceiving objects and as they were creating visual images of these objects (see Method: Brain Imaging, Chapter 2, page 41).

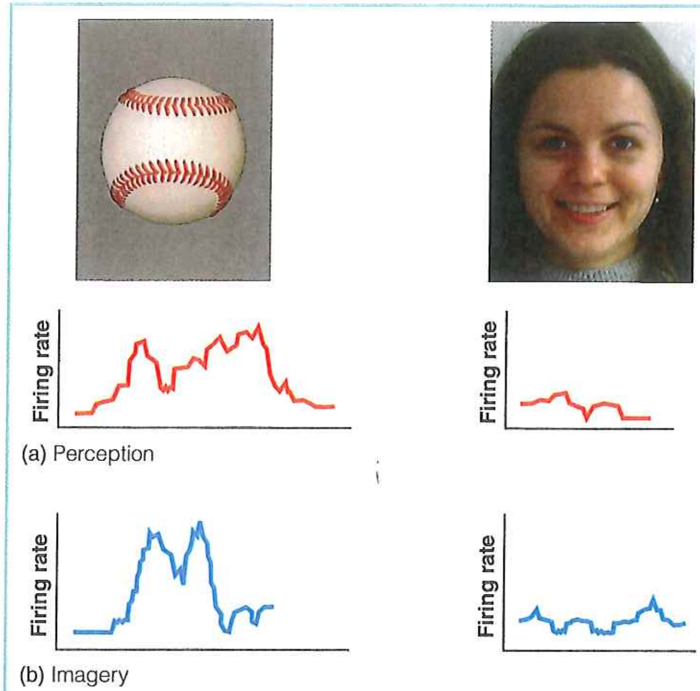

Figure 10.12 Responses of single neurons in a person's medial temporal lobe that (a) respond to perception of a baseball but not of a face, and (b) respond to imagining a baseball but not to imagining a face. *(Source: Based on G. Kreiman, C. Koch, & I. Fried, Imagery neurons in the human brain,* Nature *408, 357–361, November 16, 2000. Photos by Bruce Goldstein.)*

BRAIN IMAGING

An early study of imagery using brain imaging was carried out by Samuel Le Bihan and coworkers (1993), who demonstrated that both perception and imagery activate the visual cortex. **Figure 10.13** shows how activity in the striate cortex increased both when a person observed presentations of actual visual stimuli (marked "Perception") *and* when the person was imagining the stimulus ("Imagery"). In another brain imaging experiment, asking subjects to think about questions that involved imagery—for example, "Is the green of the trees darker than the green of the grass?"—generated a greater response in the visual cortex than asking nonimagery questions, such as "Is the intensity of electrical current measured in amperes?" (Goldenberg et al., 1989).

Another imaging experiment, by Stephen Kosslyn (1995), made use of the way the visual cortex is organized as a topographic map, which we described in Chapter 4 (see **Figure 4.35**, page 112). The topographic map refers to the fact that specific locations on a visual stimulus cause activity at specific locations in the visual cortex and that points next to each other on the stimulus cause activity at locations next to each other on the cortex.

Research on the topographic map on the visual cortex indicates that *looking* at a small object causes activity in the back of the visual cortex, as shown by the green area in **Figure 10.14a**, and looking at larger objects causes activity to spread toward the front of the visual cortex, as indicated by the red area. What would happen, Kosslyn wondered, if subjects created mental *images* of different sizes? To answer this question, subjects were instructed to create small, medium, and large visual images while they were in a brain scanner. The result, indicated by the symbols in **Figure 10.14b**, is that when subjects created small visual images, activity was centered near the back of the brain (circles), but as the size of the mental image increased, activation moved toward the front of the visual cortex (squares and triangles), just as it does for perception. (Notice that one of the triangles representing large images is near the back of the visual cortex. Kosslyn suggests that this could have been caused by activation by internal details of the larger image.) Thus, both imagery and perception result in topographically organized brain activation.

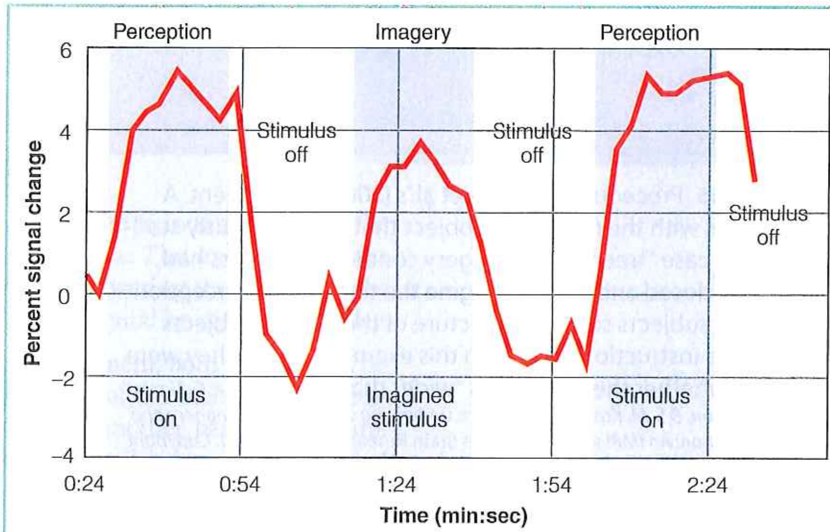

Figure 10.13 Results of Le Bihan et al.'s (1993) study measuring brain activity using fMRI. Activity increases to presentation of a visual stimulus (shaded area marked "Stimulus on") and also increases when subjects are imagining the stimulus (area marked "Imagined stimulus"). In contrast, activity is low when there is no actual or imagined stimulus. *(Source: D. Le Bihan et al., Activation of human primary visual cortex during visual recall: A magnetic resonance imaging study,* Proceedings of the National Academy of Sciences, USA, 90, *11802–11805, 1993.)*

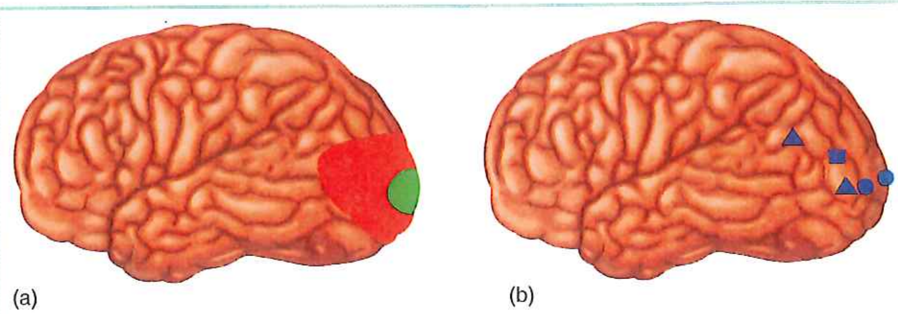

Figure 10.14 (a) Looking at a small object causes activity in the back of the visual cortex (green). Larger objects cause activity to spread forward (red). (b) Results of Kosslyn et al.'s (1995) experiment. The symbols indicate the most activated location caused by imagery: small image (circle); medium image (square); large image (triangle). *(Source: Based on S. M. Kosslyn, Mental imagery, in S. M. Kosslyn & D. N. Osherson (Eds.),* An invitation to cognitive science, *2nd ed., Vol 2, pp. 267–296, 1995.)*

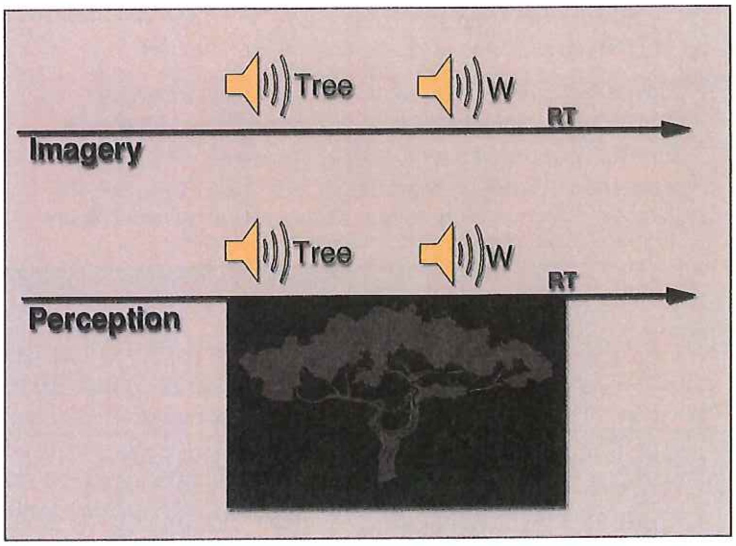

Figure 10.15 Procedure for Ganis et al.'s (2004) experiment. A trial begins with the name of an object that was previously studied, in this case "tree." In the imagery condition, subjects had their eyes closed and had to imagine the tree. In the perception condition, subjects saw a faint picture of the object. Subjects then heard instructions. The *W* in this example means they were to judge whether the object was "wider than tall." *(Source: G. Ganis, W. L. Thompson, & S. M. Kosslyn, Brain areas underlying visual mental imagery and visual perception: An fMRI study,* Cognitive Brain Research, 20, *226–241. Copyright © 2004 Elsevier Ltd. Reproduced by permission.)*

Another approach to studying imagery and the brain has been to determine whether there is overlap between brain areas activated by perceiving an object and those activated by creating a mental image of the object. These experiments have demonstrated an overlap between areas activated by perception and by imagery, but have also found differences. For example, Giorgio Ganis and coworkers (2004) used fMRI to measure activation under two conditions, perception and imagery. For the perception condition, subjects observed a drawing of an object, such as the tree in **Figure 10.15**. For the imagery condition, subjects were told to imagine a picture that they had studied before, when they heard a tone. For both the perception and imagery tasks, subjects had to answer a question such as "Is the object wider than it is tall?"

Results of Ganis's experiment are shown in **Figure 10.16**, which shows activation at three different locations in the brain. **Figure 10.16a** shows that perception and imagery both activate the same areas in the frontal lobe. **Figure 10.16b** shows the same result further back in the brain. However, **Figure 10.16c**, which shows activation in the visual cortex, in the occipital lobe at the back of the brain, indicates that perception activates much more of this area of the brain than does imagery. This greater activity for perception isn't surprising because the visual cortex is where signals from the retina first reach the cortex. Thus, there is almost complete overlap of the activation caused by perception and imagery in the front of the brain, but some difference near the back of the brain.

Other experiments have also concluded that there are similarities but also some differences between brain activation for perception and for imagery. For example, an fMRI experiment by Amir Amedi and coworkers (2005) showed overlap, but also found that when subjects were using visual imagery, some areas associated with nonvisual stimuli, such as hearing and touch, were *deactivated*. That is, during imagery, their activation was decreased. Amedi suggests that the reason for this might be that visual images are more fragile than real perception and this deactivation helps quiet down irrelevant activity that might interfere with the mental image.

The results of other imaging studies have also found both overlap and differences between activation caused by perception and imagery. For example, Sue-Hynn Lee and coworkers (2012) were able to use brain activation patterns to determine what their subjects were perceiving or imagining (see Method: Neural Mind Reading, Chapter 5, page 145). They found that activity in the visual cortex in the occipital lobe resulted in the best prediction for what their subjects were perceiving, and activity in higher visual areas was the best predictor of what their subjects were imagining. This makes sense when we remember that the visual cortex responds to small details, such as oriented lines, that would be more obvious when perceiving, and higher visual areas respond more to whole objects.

The differences in activation that are observed when comparing perception and imagery are not that surprising. After all, seeing an object is different from imagining it. As we continue describing how the brain responds to perception and imagery, we will encounter more examples of both overlap and differences.

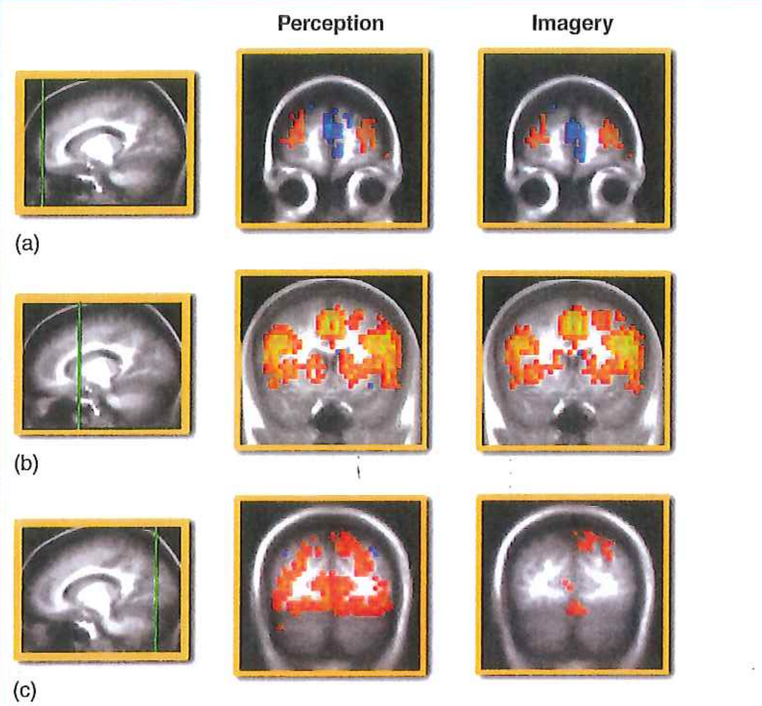

Figure 10.16 Brain scan results from Ganis et al. (2004). The vertical lines through the brains in the far left column indicate where activity was being recorded. The columns labeled "Perception" and "Imagery" indicate responses in the perception and imagery conditions. (a) Responses of areas in the frontal lobe. Perception and imagery cause the same activation. (b) Responses further back in the brain. Activation is the same in this area as well. (c) Responses from the back of the brain, including the primary visual area. There is much more activation in this area in the perception condition. *(Source: G. Ganis, W. L. Thompson, & S. M. Kosslyn, Brain areas underlying visual mental imagery and visual perception: An fMRI study,* Cognitive Brain Research, 20, *226–241. Copyright © 2004 Elsevier Ltd. Reproduced by permission.)*

TRANSCRANIAL MAGNETIC STIMULATION

Although the brain imaging experiments we have just described are consistent with the idea that imagery and perception share the same mechanisms, showing that an area of the brain is activated by imagery does not prove that this activity *causes* imagery. Pylyshyn argues that just as the spatial experience of mental images is an epiphenomenon (see page 280), brain activity can also be an epiphenomenon. According to Pylyshyn, brain activity in response to imagery may indicate that *something* is happening but may have nothing to do with causing imagery. To deal with this possibility, Stephen Kosslyn and coworkers (1999) did an experiment using transcranial magnetic stimulation (TMS), which we described in Chapter 9 (see Method: Transcranial Magnetic Stimulation (TMS), page 270).

Kosslyn and coworkers (1999) presented transcranial magnetic stimulation to the visual cortex while subjects were carrying out either a perception task or an imagery task. For the perception task, subjects briefly viewed a display like the one in **Figure 10.17** and were asked to make a judgment about the stripes in two of the quadrants. For example, they might be asked to indicate whether the stripes in quadrant 3 were longer than the stripes in quadrant 2. The imagery task was the same, but instead of actually looking at the stripes while answering the questions, the subjects closed their eyes and based their judgments on their mental image of the display.

Kosslyn measured subjects' reaction time to make the judgment, both when transcranial magnetic stimulation was being applied to the visual area of the brain and also during a control condition when the stimulation was directed to another part of the brain. The results indicated that stimulation caused subjects to respond more slowly, and that this slowing effect occurred both for perception and for imagery. Based on these results, Kosslyn concluded that the brain activation that occurs in response to imagery is not an epiphenomenon and that brain activity in the visual cortex plays a causal role in both perception and imagery.

NEUROPSYCHOLOGICAL CASE STUDIES

How can we use studies of people with brain damage to help us understand imagery? One approach is to determine how brain damage affects imagery. Another approach is to determine how brain damage affects both imagery and perception, and to note whether both are affected in the same way.

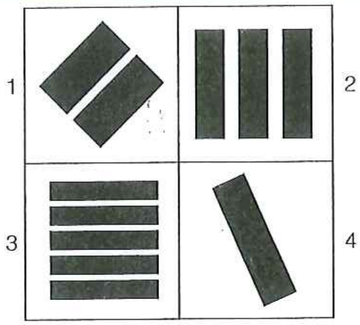

Figure 10.17 Bar stimuli used for Kosslyn et al.'s (1999) experiment. Subjects created visual images of displays such as this and answered questions about the stripes. *(Source: S. M. Kosslyn, A. Pascual-Leone, O. Felician, S. Camposano, J. P. Keenan, W. L. Thompson, et al., The role of area 17 in visual imagery: Convergent evidence form PET and rTMS,* Science, 284, *167–170, 1999.)*

REMOVING PART OF THE VISUAL CORTEX DECREASES IMAGE SIZE Patient M.G.S. was a young woman who was about to have part of her right occipital lobe removed as treatment for a severe case of epilepsy. Before the operation, Martha Farah and coworkers (1993) had M.G.S. perform the mental walk task that we described earlier, in which she imagined walking toward an animal and estimated how close she was when the image began to overflow her visual field. **Figure 10.18** shows that before the operation, M.G.S. felt she was about 15 feet from an imaginary horse before its image overflowed. But when Farah had her repeat this task after her right occipital lobe had been removed, the distance increased to 35 feet. This occurred because removing part of the visual cortex reduced the size of her field of view, so the horse filled up the field when she was farther away. This result supports the idea that the visual cortex is important for imagery.

PERCEPTUAL PROBLEMS ARE ACCOMPANIED BY PROBLEMS WITH IMAGERY A large number of cases have been studied in which a patient with brain damage has a perceptual problem and also has a similar problem in creating images. For example, people who have lost the ability to see color due to brain damage are also unable to create colors through imagery (DeRenzi & Spinnler, 1967; DeVreese, 1991).

Damage to the parietal lobes can cause a condition called **unilateral neglect**, in which the patient ignores objects in one half of the visual field, even to the extent of shaving just one side of his face or eating only the food on one side of her plate. Edoardo Bisiach and Claudio Luzzatti (1978) tested the imagery of a patient with unilateral neglect by asking him to describe things he saw when imagining himself standing at one end of the Piazza del Duomo in Milan, a place with which he had been familiar before his brain was damaged (**Figure 10.19**).

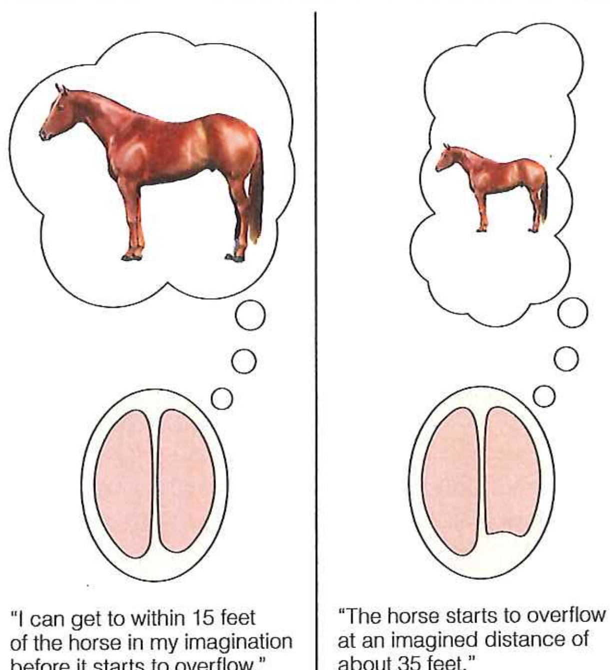

Figure 10.18 Results of the mental walk task for patient M.G.S. *Left*: Before her operation, she could mentally "walk" to within 15 feet before the image of the horse overflowed her visual field. *Right*: After removal of the right occipital lobe, the size of the visual field was reduced, and she could mentally approach only to within 35 feet of the horse before it overflowed her visual field. *(Source: Based on M. J. Farah, The neural basis of mental imagery, in M. Gazzaniga, ed.,* The cognitive neurosciences, *2nd ed., Cambridge, MA: MIT Press, pp. 965–974, Figure 66.2, 2000.)*

The patient's responses showed that he neglected the left side of his mental image, just as he neglected the left side of his perceptions. Thus, when he imagined himself standing at A, he neglected the left side and named only objects to his right (small *a*'s). When he imagined himself standing at B, he continued to neglect the left side, again naming only objects on his right (small *b*'s).

The correspondence between the physiology of mental imagery and the physiology of perception, as demonstrated by brain scans in normal subjects and the effects of brain damage in subjects with neglect, supports the idea that mental imagery and perception share physiological mechanisms. However, not all physiological results support a one-to-one correspondence between imagery and perception.

DISSOCIATIONS BETWEEN IMAGERY AND PERCEPTION In Chapter 2 we described dissociations between different types of perception, in which some people with brain damage were unable to recognize faces but could recognize objects and other people had the opposite problem (see Method: Demonstrating a Double Dissociation, Chapter 2, page 40). Cases have also been reported of dissociations between imagery and perception. For example, Cecilia Guariglia and coworkers (1993) studied a patient whose brain damage had little effect on his ability to perceive but caused neglect in his mental images (his mental images were limited to only one side, as in the case of the man imagining the piazza in Milan).

Another case of normal perception but impaired imagery is the case of R.M., who had suffered damage to his occipital and parietal lobes (Farah et al., 1988). R.M. was able to recognize objects and to draw accurate pictures of objects that were placed before him. However, he was unable to draw objects from memory, a task that requires imagery. He also had trouble answering questions that depend on imagery, such as verifying whether the sentence "A grapefruit is larger than an orange" is correct.

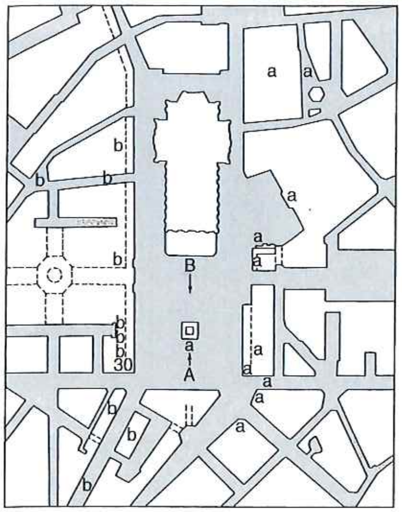

Figure 10.19 Piazza del Duomo in Milan. When Bisiach and Luzzatti's (1978) patient imagined himself standing at A, he could name objects indicated by *a*'s. When he imagined himself at B, he could name objects indicated by *b*'s. *(Source: Based on E. Bisiach & G. Luzzatti, Unilateral neglect of representational space,* Cortex, 14, *129–133, 1978.)*

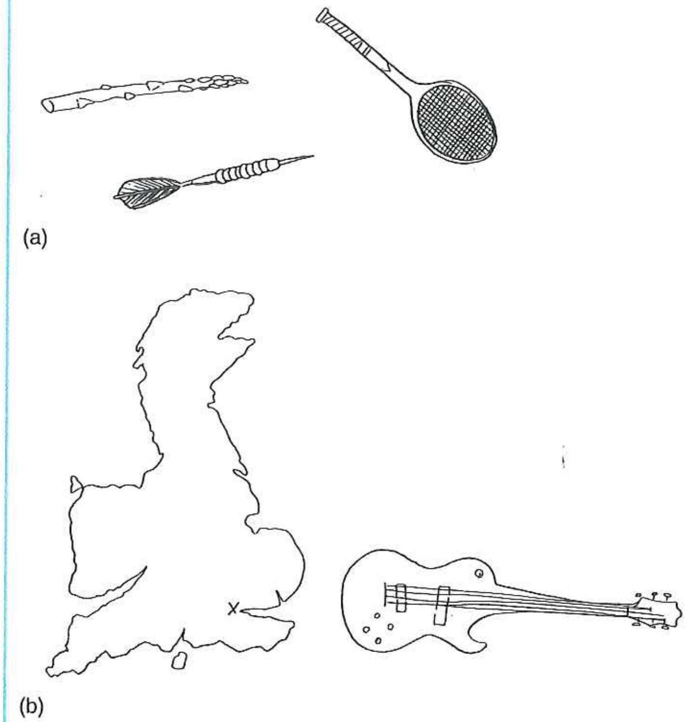

Figure 10.20 (a) Pictures incorrectly labeled by C.K., who had visual agnosia. (b) Drawings from memory by C.K. *(Source: From M. Behrmann et al., Intact visual imagery and impaired visual perception in a patient with visual agnosia,* Journal of Experimental Psychology: Human Perception and Performance, 30, *1068–1087, Figures 1 & 6, 1994.)*

Dissociations have also been reported with the opposite result, so that perception is impaired but imagery is relatively normal. For example, Marlene Behrmann and coworkers (1994) studied C.K., a 33-year-old graduate student who was struck by a car as he was jogging. C.K. suffered from visual agnosia, the inability to visually recognize objects. Thus, he labeled the pictures in **Figure 10.20a** as a "feather duster" (the dart), a "fencer's mask" (the tennis racquet), and a "rose twig with thorns" (the asparagus). These results show that C.K. could recognize parts of objects but couldn't integrate them into a meaningful whole. But despite his inability to name pictures of objects, C.K. was able to draw objects from memory, a task that depends on imagery (**Figure 10.20b**). Interestingly, when he was shown his own drawings after enough time had passed so he had forgotten the actual drawing experience, he was unable to identify the objects he had drawn.

MAKING SENSE OF THE NEUROPSYCHOLOGICAL RESULTS The neuropsychological cases present a paradox: On one hand, there are many cases that show close parallels between perceptual deficits and deficits in imagery. On the other hand, there are a number of cases in which dissociations occur, so that perception is normal but imagery is poor (Guariglia's patient and R.M.), or perception is poor but imagery is normal (C.K.). The cases in which imagery and perception are affected differently by brain damage provide evidence for a double dissociation between imagery and perception (**Table 10.1**). The presence of a double dissociation is usually interpreted to mean that the two functions (perception and imagery, in this case) are served by different mechanisms (see page 40). However, this conclusion contradicts the other evidence we have presented that shows that imagery and perception share mechanisms.

One way to explain this paradox, according to Behrmann and coworkers (1994), is that the mechanisms of perception and imagery overlap only partially, with the mechanism

Table 10.1: Dissociations Between Perception and Imagery

CASE	PERCEPTION	IMAGERY
Guariglia (1993)	OK.	Neglect (image limited to one side).
Farah et al. (1993) (R.M.)	OK. Recognizes objects and can draw pictures.	Poor. Can't draw from memory or answer questions based on imagery.
Behrmann et al. (1994) (C.K.)	Poor. Visual agnosia, can't recognize objects.	OK. Can draw object from memory.

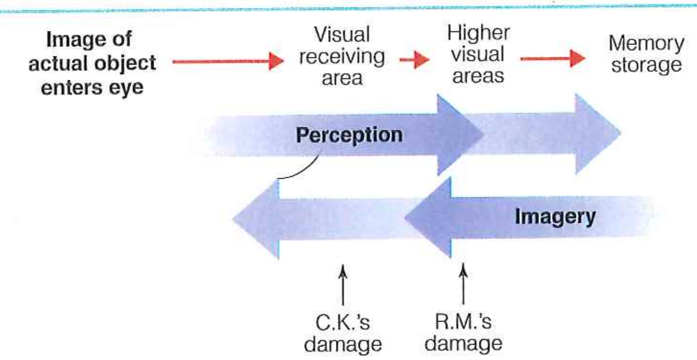

Figure 10.21 Depiction of the idea that mechanisms serving perception, which starts when an image of the actual object enters the eye, are located at both lower and higher visual centers and that mechanisms serving imagery are located mainly at higher levels (Behrmann et al., 1994). The general locations of damage for C.K. and R.M. are indicated by the vertical arrows. These locations can explain why C.K. has a perceptual problem but can still create images, and why R.M. has trouble creating images but can still perceive.

for perception being located at both lower and higher visual centers and the mechanism for imagery being located mainly in higher visual centers (Figure 10.21). According to this idea, visual perception necessarily involves *bottom-up processing*, which starts when light enters the eye and an image is focused on the retina, then continues as signals are sent along the visual pathways to the visual cortex and then to higher visual centers.

The visual cortex is crucial for perception because it is here that objects begin being analyzed into components like edges and orientations. This information is then sent to higher visual areas, where perception is "assembled," and top-down processing, which involves a person's prior knowledge, may also be involved (see page 59). In contrast, imagery *originates* as a top-down process, in higher brain areas that are responsible for memory.

Based on this explanation, we can hypothesize that C.K.'s difficulty in perceiving is caused by damage early in the processing stream, but that he can still create images because higher-level areas of his brain are intact. Similarly, we can hypothesize that R.M.'s difficulty in creating mental images is caused by damage to higher-level areas, where mental images originate, but that he can perceive objects because areas earlier in the processing stream are still functioning.

Although this explanation works for C.K. and R.M., it can't explain the case of M.G.S., the woman who had part of her visual cortex removed (see Figure 10.18). Even though M.G.S.'s damage was earlier in the cortex, she experienced changes in both perception and imagery. Cases such as this emphasize the challenge of interpreting the results of neuropsychological research. It is likely that further research will lead to modifications in the explanation shown in Figure 10.21, or perhaps a new explanation altogether.

CONCLUSIONS FROM THE IMAGERY DEBATE

The imagery debate provides an outstanding example of a situation in which a controversy has motivated a large amount of research. Most psychologists, looking at the behavioral and physiological evidence, have concluded that imagery and perception are closely related and share some (but not all) mechanisms (but see Pylyshyn, 2001, 2003, who doesn't agree).

The idea of shared mechanisms follows from all of the parallels and interactions between perception and imagery. The idea that not all mechanisms are shared follows from some of the fMRI results, which show that the overlap between brain activation is not complete; some of the neuropsychological results, which show dissociations between imagery and perception; and also from differences between the experience of imagery and perception. For example, perception occurs automatically when we look at something, but imagery needs to be generated with some effort. Also, perception is stable—it continues as long as you are observing a stimulus—but imagery is fragile—it can vanish without continued effort.

Another example of a difference between imagery and perception is that it is harder to manipulate mental images than images that are created perceptually. This was demonstrated by Deborah Chalmers and Daniel Reisberg (1985), who asked their subjects to create mental images of ambiguous figures such as the one in **Figure 10.22**, which can be seen as a rabbit or a duck. Perceptually, it is fairly easy to "flip" between these two perceptions. However, Chalmers and Reisberg found that subjects who were holding a mental image of this figure were unable to flip from one perception to another.

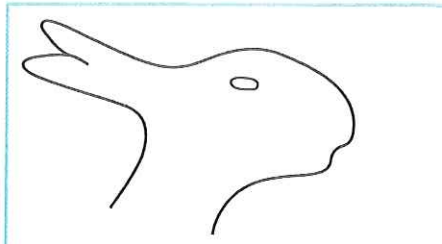

Figure 10.22 What is this, a rabbit (facing right) or a duck (facing left)? © Cengage Learning

Later research has shown that people can manipulate simpler mental images. For example, Ronald Finke and coworkers (1989) showed that when subjects followed instructions to imagine a capital letter D, and then rotate it 90 degrees to the left and place a capital letter J at the bottom, they reported seeing an umbrella. Also, Fred Mast and Kosslyn (2002) showed that people who were good at imagery were able to rotate mental images of ambiguous figures if they were provided with extra information such as drawings of parts of the images that are partially rotated. So, the experiments on manipulating images lead to the same conclusion as all of the other experiments we have described: Imagery and perception have many features in common, but there are also differences between them.

Using Imagery to Improve Memory

It is clear that imagery can play an important role in memory. But how can you harness the power of imagery to help you remember things better? In Chapter 7 we saw that encoding is aided by forming connections with other information and described an experiment (Bower & Winzenz, 1970) in which subjects who created images based on two paired words (like *boat* and *tree*) remembered more than twice as many words as subjects who just repeated the words (see **Figure 7.2**, page 182). Another principle of memory we described in Chapter 7 was that organization improves encoding. The mind tends to spontaneously organize information that is initially unorganized, and presenting information that is organized improves memory performance. We will now describe a method based on these principles, which involves placing images at locations.

PLACING IMAGES AT LOCATIONS

The power of imagery to improve memory is tied to its ability to create organized locations at which memories for specific items can be placed. An example of the organizational function of imagery from ancient history is provided by a story about the Greek poet Simonides. According to legend, 2,500 years ago Simonides presented an address at a banquet, and just after he left the banquet, the roof of the hall collapsed, killing most of the people inside. To compound this tragedy, many of the bodies were so severely mutilated that they couldn't be identified. But Simonides realized that as he had looked out over the audience during his address, he had created a mental picture of where each person had been seated at the banquet table. Based on this image of people's locations around the table, he was able to determine who had been killed.

What is important about this rather gory example is that Simonides realized that the technique he had used to help him remember who was at the banquet could be used to remember other things as well. He found that he could remember things by imagining a physical space, like the banquet table, and placing, in his mind, items to be remembered in the seats surrounding the table. This feat of mental organization enabled him to later "read out" the items by mentally scanning the locations around the table, just as he had done to identify people's bodies. Simonides had invented what is now called the **method of loci**—a method in which things to be remembered are placed at different locations in a mental image of a spatial layout. The following demonstration illustrates how to use the method of loci to remember something from your own experience.

DEMONSTRATION
METHOD OF LOCI

Pick a place with a spatial layout that is very familiar to you, such as the rooms in your house or apartment, or the buildings on your college campus. Then pick five to seven things that you want to remember—either events from the past or things you need to do later today. Create an image representing each event, and place each image at a location in the house or on campus. If you need to remember the events in a particular order, decide on a path you would take while walking through the house or campus, and place the images representing each event along your walking path so they will be encountered in the correct order. After you have done this, retrace the path in your mind, and see if encountering the images helps you remember the events. To really test this method, try mentally "walking" this path a few hours from now.

Placing images at locations can help with retrieving memories later. For example, to help me remember a dentist appointment later in the day, I could visually place a huge pair of teeth in my living room. To remind myself to go to the gym and work out, I could imagine an elliptical trainer on the stairs that lead from the living room to the second floor, and to represent the *NCIS* TV show that I want to watch later tonight, I could imagine one of the characters on the show sitting on the landing at the top of the stairs.

Figure 10.23 An image used by the author to remember a dentist appointment, using the pegword technique. © Cengage Learning

ASSOCIATING IMAGES WITH WORDS

The **pegword technique** involves imagery, as in the method of loci, but instead of visualizing items in different locations, you associate them with concrete words. The first step is to create a list of nouns, like the following: one–bun; two–shoe; three–tree; four–door; five–hive; six–sticks; seven–heaven; eight–gate; nine–mine; ten–hen. It's easy to remember these words in order because they were created by rhyming them with the numbers. Also, the rhyming provides a retrieval cue (see page 183) that helps remember each word. The next step is to pair each of the things to be remembered with a pegword by creating a vivid image of your item-to-be-remembered together with the object represented by the word.

Figure 10.23 shows an image I created for the dentist appointment. For the other items I wanted to remember, I might picture an elliptical trainer inside a shoe, and the letters *N, C, I,* and *S* in a tree. The beauty of this system is that it makes it possible to immediately identify an item based on its order on the list. So if I want to identify the third thing I need to do today, I go straight to *tree,* which translates into my image of the letters *N, C, I,* and *S* dangling in a tree, and this reminds me to watch the program *NCIS* on TV.

Imagery techniques like the ones just described are often the basis behind books that claim to provide the key to improving your memory (see Crook & Adderly, 1998; Lorayne & Lucas, 1996; Treadeau, 1997). Although these books do provide imagery-based techniques that work, people who purchase these books in the hope of discovering an easy way to develop "photographic memory" are often disappointed. Although imagery techniques work, they do not provide easy, "magical" improvements in memory, but rather require a great deal of practice and perseverance (Schacter, 2001).

Something to Consider

VISUAL IMAGERY AND FOOD CRAVING

Have you ever had an intense desire to eat a specific food? If so, you have experienced **food craving**, which goes beyond ordinary hunger because of its intensity and specificity (Kemps & Tiggemann, 2013; Weingarten & Elston, 1990). A large proportion of the general population experiences food craving with no problems (Lafay et al., 2001). (The most common food craved in Western societies is, not surprisingly, chocolate; Hetherington & Macdiarmid, 1993.) However, recurrent craving has been associated with problems such as overeating, sabotaging attempts at dieting, and binge eating associated with eating disorders, especially in women (Waters et al., 2001).

Food craving is caused by a number of factors, including nutritional deficiencies, hormonal changes, emotions, and proximity to enticing foods (Kemps & Tiggemann, 2013). But in addition to these biological and psychological factors, food craving is also associated with cognitive factors, including imagery. Thus, people often describe their craving experience with statements such as "I am imagining the taste of it," or "I am visualizing it" (Tiggemann & Kemps, 2005).

Evidence that imagery can cause food craving has been provided by Kirsty Harvey and coworkers (2005), who had female subjects rate their intensity of craving on a 100-point scale and then divided them into two groups. The *food imagery group* were told to imagine their favorite food. The *holiday imagery group* were told to imagine their favorite holiday. Following this imagery, subjects again rated their food craving. The results, shown in **Figure 10.24**, indicate that the food imagery task caused a large increase in craving, but the holiday imagery task had no effect. Interestingly, the effect of imagery was greater in women who were dieting, although the increase in craving occurred in nondieters as well.

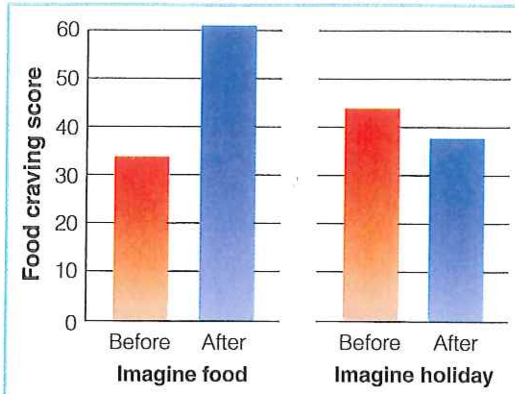

Figure 10.24 Food craving ratings for subjects before and after imagining their favorite food (left pair of bars) or their favorite holiday (right bars). Imagining food increased subjects' rating of the intensity of food craving. These data are for dieters. *(Source: K. Harvey, E. Kemps, & M. Tiggemann, The nature of imagery processes underlying food cravings,* British Journal of Health Psychology, *10, 49–56, 2005.)*

While food imagery can increase craving, there is evidence that nonfood imagery can *decrease* craving. Harvey and coworkers demonstrated this by dividing subjects that were in the food imagery group into two groups. Subjects in the *visual imagery group* were asked to close their eyes and create images based on visual cues ("Imagine the appearance of a rainbow"). Subjects in the *auditory imagery group* created images based on auditory cues ("Imagine the sound of a telephone ringing.") Food craving ratings measured before and after these imagery experiences, shown in **Figure 10.25a**, indicate that food craving is reduced following both visual and auditory imagery, but the effect is larger for the visual group.

Harvey explains the larger effect of visual imagery in terms of Baddeley and Hitch's (1974) model of working memory, which we described in Chapter 5 (see page 134). According to this model, shown in **Figure 10.25b**, the phonological loop, which is responsible for processing visual and auditory information, is involved in creating the auditory images, and the visuospatial sketch pad, which is responsible for visual and spatial information, is involved in creating the visual images.

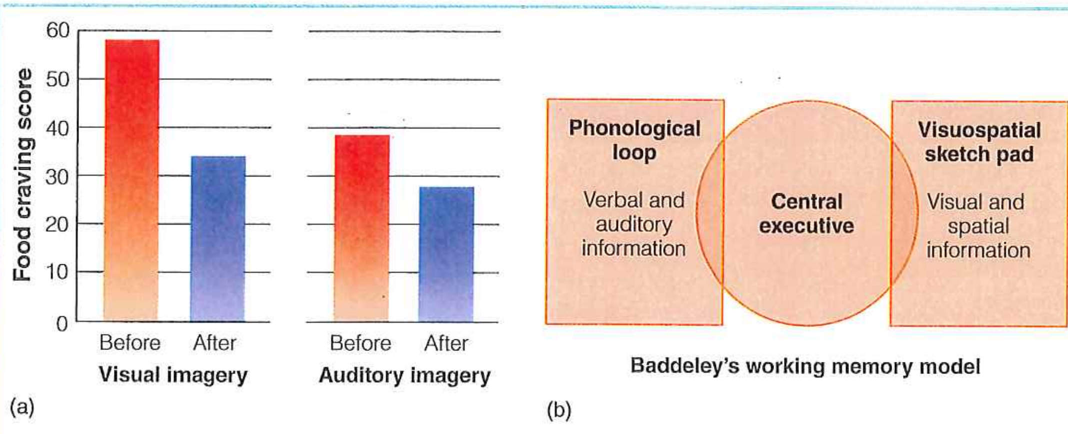

Figure 10.25 (a) Food craving ratings for subjects before and after nonfood-related visual imagery (left pair of bars) or auditory imagery (right bars). Visual imagery caused a greater decrease in food craving. (b) Baddeley and Hitch's (1974) working memory model, described in Chapter 5. *(Source: part a, based on K. Harvey, E. Kemps, & M. Tiggemann, The nature of imagery processes underlying food cravings,* British Journal of Health Psychology, *10, 49–56, Table 2, 2005; part b, © Cengage Learning.)*

Harvey suggests that the nonfood visual imagery uses some of the capacity of the visuospatial sketch pad, so food-related imagery is reduced. The smaller effect of the auditory imagery occurs because auditory images would affect the phonological loop but not the visuospatial sketch pad. It is possible that the small effect observed for the auditory imagery group could be due to unintended visual imagery, as would occur if a person imagines what a telephone looks like as they imagine the telephone's sound.

A number of other laboratory studies have shown that nonfood visual imagery can reduce food cravings and decrease eating associated with craving (Kemps & Tiggemann, 2007). Recently, the effect of nonfood visual imagery on craving has been demonstrated in a 4-week field study. Eva Kemps and Marika Tiggemann (2013) had subjects carry a handheld device that produced a display of dynamic visual noise (randomly moving dots). Subjects were instructed to activate the device and look at the visual noise every time they experienced craving. The idea here, as with the previously described studies, is that the visual noise pattern uses some of the capacity of the phonological loop and reduces the intensity of the food-related imagery that is often associated with craving. As expected, viewing the visual noise decreased food craving and related food consumption. Perhaps, suggest Kemps and Tiggemann, an anticraving app could be developed that would generate visual patterns to look at every time you feel a craving coming on!

TEST YOURSELF 10.2

1. Describe how experiments using the following physiological techniques have provided evidence of parallels between imagery and perception: (a) brain imaging; (b) deactivation of part of the brain; (c) neuropsychology; and (d) recording from single neurons.
2. Some of the neuropsychological results demonstrate parallels between imagery and perception, and some results do not. How has Behrmann explained these contradictory results?
3. What are some differences between imagery and perception? What have most psychologists concluded about the connection between imagery and perception?
4. Under what conditions does imagery improve memory? Describe techniques that use imagery as a tool to improve memory. What is the basic principle that underlies these techniques?
5. What is the relationship between food craving and visual imagery? How has visual imagery been used to reduce food craving?

CHAPTER SUMMARY

1. Mental imagery is experiencing a sensory impression in the absence of sensory input. Visual imagery is "seeing" in the absence of a visual stimulus. Imagery has played an important role in the creative process and as a way of thinking in addition to purely verbal techniques.
2. Early ideas about imagery included the imageless thought debate and Galton's work with visual images, but imagery research stopped during the behaviorist era. Imagery research began again in the 1960s with the advent of the cognitive revolution.
3. Kosslyn's mental scanning experiments suggested that imagery shares the same mechanisms as perception (that is, creates a depictive representation in the person's mind), but these results and others were challenged by Pylyshyn, who stated that imagery is based on a mechanism related to language (that is, it creates a propositional representation in a person's mind).
4. One of Pylyshyn's arguments against the idea of a depictive representation is the tacit knowledge explanation, which states that when asked to imagine something, people ask themselves what it would look like to see it and then simulate this staged event.
5. Finke and Pinker's "flashed dot" experiment argued against the tacit knowledge explanation. The following experiments also demonstrated parallels between imagery and perception: (a) size in the visual field (visual walk task); (b) interaction between perception and imagery (Perky's 1910 experiment; Farah's experiment in which subjects imagined H or T); and (c) physiological experiments.

6. Parallels between perception and imagery have been demonstrated physiologically by the following methods: (a) recording from single neurons (imagery neurons); (b) brain imaging (demonstrating overlapping activation in the brain); (c) transcranial magnetic stimulation experiments (comparing the effect of brain inactivation on perception and imagery); and (d) neuropsychological case studies (removal of visual cortex affects image size; unilateral neglect).

7. There is also physiological evidence for differences between imagery and perception. This evidence includes (a) differences in areas of the brain activated and (b) brain damage causing dissociations between perception and imagery.

8. Most psychologists, taking all of the above evidence into account, have concluded that imagery is closely related to perception and shares some (but not all) mechanisms.

9. The use of imagery can improve memory in a number of ways: (a) visualizing interacting images; (b) organization using the method of loci; and (c) associating items with nouns using the pegword technique.

10. Food craving has been associated with food-related visual imagery. A reduction in food craving has been associated with nonfood-related visual imagery. It has been suggested that this reduction in food craving occurs because the nonfood-related imagery uses some of the capacity of the visuospatial sketch pad.

THINK ABOUT IT

1. Look at an object for a minute; then look away, create a mental image of it, and draw a sketch of the object based on your mental image. Then draw a sketch of the same object while you are looking at it. What kinds of information about the object in the imagery drawing were omitted, compared to the sketch you made while looking at the object?

2. Write a description of an object as you are looking at it. Then compare the written description with the information you can obtain by looking at the object or at a picture of the object. Is it true that "a picture is worth a thousand words"? How does your comparison of written and visual representations relate to the discussion of propositional versus depictive representations in this chapter?

3. Try using one of the techniques described at the end of this chapter to create images that represent things you have to do later today or during the coming week. Then, after some time passes (anywhere from an hour to a few days), check to see whether you can retrieve the memories for these images and if you can remember what they stand for.

KEY TERMS

Conceptual peg hypothesis, 278
Depictive representation, 280
Epiphenomenon, 280
Food craving, 292
Imageless thought debate, 277
Imagery debate, 279
Imagery neuron, 284
Mental chronometry, 278
Mental imagery, 276
Mental scanning, 278
Mental walk task, 282
Method of loci, 291
Paired-associate learning, 277
Pegword technique, 292
Propositional representation, 280
Spatial representation, 279
Tacit knowledge explanation, 281
Unilateral neglect, 288
Visual imagery, 276

COGLAB EXPERIMENTS Numbers in parentheses refer to the experiment number in CogLab.

Link Word (37)

Mental Rotation (38)