Unit IV

Sensation and Perception

Unit Overview

We rely on our senses to understand the world around us. The sense organs—the eyes, ears, nose, tongue, and skin—receive signals from the environment (sensation) and transfer those signals to the brain, which processes the signals so we can understand them (perception). In this unit, we look first at the processes of sensation, the ways in which the sense organs receive signals from the environment. The eyes receive light waves. The ears receive sound waves. The nose and tongue receive chemical signals, and the skin receives signals related to pressure, warmth, body position, and pain. Next, perception is examined. The brain processes and organizes these signals in interesting ways. Most of the time, our perceptions reflect the reality of the world around us. Sometimes, though, our own expectations and the brain's desire to organize cause our perceptions to differ from reality and allow illusions to fool us. By studying how we sense and perceive the world, we can understand more about ourselves and the world around us.

This unit will help students appreciate how sensation and perception interact to influence our thoughts and behaviors. The integrated processes of sensation and perception are the most basic ways we interact with the world. By studying this unit, students will be able to:

- Differentiate between sensation and perception, understanding that these processes are interrelated.
- Understand how much information can be processed at any given point in time.
- Discuss basic sensory concepts, such as thresholds and adaptation.
- Appreciate how expectations, contexts, emotions, and motivation influence perceptions.
- Evaluate claims of ESP and the conclusions drawn from research on those claims.
- Explain how the eyes receive, process, and transform light signals.
- Differentiate among the theories that explain our sensation and perception of color.
- Describe gestalt perceptual principles, including figure–ground and grouping principles.
- Differentiate among the binocular and monocular depth cues that help us perceive 3D and motion.
- Understand how perceptual constancies help us create meaning from sensory signals.
- Describe research on restored vision, sensory restriction, and perceptual adaptation and how it contributes our understanding of perception.
- Explain how the ears process sound waves, contributing to our perception of pitch and sound location.
- Describe how the senses of touch, pain, taste, smell, and body position and movement work.
- Explain how the senses interact.

Alignment to AP® Course Description

Topic 4: Sensation and Perception (6–8% of AP® Examination)

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### Unit Resources

#### Module 16

**STUDENT ACTIVITIES:**
- Fact or Falsehood?
- The Stroop Effect Online
- Understanding Weber's Law

**FLIP IT VIDEOS**
- Top-Down and Bottom-Up Processing
- Signal Detection Theory

#### Module 17

**TEACHER DEMONSTRATIONS**
- Testing for ESP
- ESP Trick—Precognition (Playing Card Trick)
- ESP Trick—Precognition (Newspaper Article Trick)
- ESP Trick—Clairvoyance
- ESP Trick—Mental Telepathy (Gray Elephant in Denmark Trick)
- ESP Trick—Mental Telepathy (Telephone Book Trick)

**STUDENT ACTIVITIES**
- Fact or Falsehood?
- Belief in ESP Scale

#### Module 18

**TEACHER DEMONSTRATION**
- Movement Aftereffects

**STUDENT ACTIVITIES:**
- Fact or Falsehood?
- Locating the Retinal Blood Vessels
- Subjective Colors
- The Color Vision Screening Inventory and Color Blindness

**FLIP IT VIDEOS**
- Rods and Cones in the Retina
- Feature Detectors

#### Module 19

**STUDENT ACTIVITIES**
- Fact or Falsehood?
- Binocular Vision vs. Monocular Vision
- Autostereograms
- Perceived Lunar Size
- The Ganzfeld
- Displacement Goggles

**FLIP IT VIDEOS**
- Gestalt Psychology
- Monocular Cues

#### Module 20

**STUDENT ACTIVITY**
- Fact or Falsehood?

**FLIP IT VIDEO**
- Theories of Hearing

#### Module 21

**TEACHER DEMONSTRATIONS**
- Vision and Taste

**STUDENT ACTIVITIES**
- Fact or Falsehood?
- Warm Plus Cold Equals Hot
- Tasting Salt and Sugar

**FLIP IT VIDEO**
- Theories of Pain
"I have perfect vision," explains my colleague, Heather Sellers, an acclaimed writer and teacher. Her vision may be fine, but there is a problem with her perception. She cannot recognize faces.

In her memoir, You Don't Look Like Anyone I Know, Sellers (2010) tells of awkward moments resulting from her lifelong prosopagnosia—face blindness.

In college, on a date at the Spaghetti Station, I returned from the bathroom and plunked myself down in the wrong booth, facing the wrong man. I remained unaware he was not my date even as my date (a stranger to me) accosted Wrong Booth Guy, and then stormed out of the Station. I can't distinguish actors in movies and on television. I do not recognize myself in photos or videos. I can't recognize my stepsons in the soccer pick-up line; I failed to determine which husband was mine at a party, in the mall, at the market.

Her inability to recognize faces means that people sometimes perceive her as snobby or aloof. "Why did you walk past me?" a neighbor might later ask. Similar to those of us with hearing loss who fake hearing during trite social conversation, Sellers sometimes fakes recognition. She often smiles at people she passes, in case she knows them. Or she pretends to know the person with whom she is talking. (To avoid the stress associated with such perception failures, people with serious hearing loss or with prosopagnosia often shy away from busy social situations.)
Basic Principles of Sensation and Perception

Module Learning Objectives

1. Contrast sensation and perception, and explain the difference between bottom-up and top-down processing.
2. Discuss how much information we can consciously attend to at once.
3. Identify the three steps that are basic to all our sensory systems.
4. Distinguish between absolute and difference thresholds, and discuss whether we can sense and be affected by stimuli below the absolute threshold.
5. Explain the function of sensory adaptation.

There is an upside: When encountering someone who previously irritated her, she typically won't feel ill will, because she doesn't recognize the person.

Unlike Sellers, most of us have (as Module 18 explains) a functioning area on the underside of our brain’s right hemisphere that helps us recognize a familiar human face as soon as we detect it—in only one-seventh of a second (Jacques & Rossion, 2006). This ability illustrates a broader principle: Nature’s sensory gifts enable each animal to obtain essential information. Some examples:

- Frogs, which feed on flying insects, have cells in their eyes that fire only in response to small, dark, moving objects. A frog could starve to death knee-deep in motionless flies. But let one zoom by and the frog’s “bug detector” cells snap awake.
- Male silkworm moth’s odor receptors can detect one-billionth of an ounce of sex attractant per second released by a female one mile away. That is why silkworms continue to be.
- Human ears are most sensitive to sound frequencies that include human voices, especially a baby’s cry.

In this unit, we’ll look more closely at what psychologists have learned about how we sense and perceive the world around us.

Module 16

Basic Principles of Sensation and Perception

Discussion Starter

Use the Module 16 Fact or Falsehood? student activity from the TRM to introduce the concepts from this module.

Teaching Tip

This unit provides numerous opportunities for active learning. Don’t be afraid to use your time to do the activities suggested in the text and from the accompanying Teacher’s Resource Materials. Students will understand the information better if they are able to experience the material firsthand.

Online Activities

Use any or all of the following sites to help prepare for this unit or to give to students to explore:

- The Internet Psychology Lab (IPL) at www.ipsych.com.

The Online Psychology Laboratory (OPL) is an excellent website that has online experiments in all areas of psychology, especially sensation and perception, that students can participate in and download results to analyze. Using a computer lab, students can participate in several different experiments or ones that you choose by accessing http://opl.apa.org.
**TEACH**

**Flip It**
Help your students understand top-down and bottom-up processing better by assigning the Flip It Video: Top-Down and Bottom-Up Processing.

**TEACH**

**Concept Connections**
Students may more readily identify top-down processing with stereotyping because both use previous expectations to make judgments about the world around us. Help students understand that although stereotyping can be negative, it can also be very efficient for people as they interact with certain stimuli. Without top-down processing, we would have to interpret the world as if it were constantly new. It would be like having to relearn how to add in math class every single day!

**TEACH**

**Common Pitfalls**
Students may get bottom-up and top-down processing confused. Help students remember the difference between the 2 concepts with these tips:
- **Bottom-up processing**—we process this way when we have no prior knowledge. We start at the bottom and work our way up.
- **Top-down processing**—we process this way when we have prior knowledge. We start at the top and work to process details.

**ENGAGE**

**Online Activities**
Use this series of photos from the Tai-Wiki-Widbee blog to see if students notice glaring incongruities from a Colgate® dental floss ad campaign: http://tywkiwdbi.blogspot.com/2013/01/what-do-you-notice-about-these-photos.html.
Selective Attention and Accidents

Test or talk on the phone while driving, or attend to a music player or GPS, and your selective attention will shift back and forth between the road and its electronic competition. But when a demanding situation requires it, you’ll probably give the road your full attention. You’ll probably also blink less. When focused on a task, such as reading, people blink less than when their mind is wandering (Smilek et al., 2010). If you want to know whether your dinner companion is focused on what you’re saying, watch for eyblinks and hope there won’t be too many.

We pay a toll for switching attentional gears, especially when we shift to complex tasks, like noticing and avoiding cars around us. The toll is a slight and sometimes fatal delay in coping (Rubenstein et al., 2001). About 28 percent of traffic accidents occur when people are chatting on cell phones or texting (National Safety Council, 2010). One study tracked long-haul truck drivers for 18 months. The video cameras mounted in their cabs showed they were at 23 times greater risk of a collision while texting (VTTI, 2009). Mindful of such findings, the United States in 2010 banned truckers and bus drivers from texting while driving (Halsey, 2010).

It’s not just truck drivers who are at risk. One in four teen drivers with cell phones admitted to texting while driving (Pew, 2009). Multitasking comes at a cost: fMRI scans offer a biological account of how multitasking distracts from brain resources allocated to driving. They show that brain activity in areas vital to driving decreases an average 37 percent when a driver is attending to conversation (Just et al., 2008).

Even hands-free cell-phone talking is more distracting than a conversation with passengers, who can see the driving demands and pause the conversation. When University of Sydney researchers analyzed phone records for the moments before a car crash, they found that cell-phone users (even with hands-free sets) were four times more at risk (McEvoy et al., 2005, 2007). Having a passenger increased risk only 1.6 times. This risk difference also appeared in an experiment that asked drivers to pull off at a freeway turn stop 8 miles ahead. Of drivers conversing with a passenger, 88 percent did so. Of those talking on a cell phone, 50 percent drove on by (Strayer & Drews, 2007).

AP® Exam Tip
You may wish to know about how the information on selective attention relates to something a little less dangerous: studying. The same principles apply. The more time you spend texting, tweeting, and Facebooking, the less focused you’ll be on the material you’re trying to master. A better strategy is to spend 25 minutes doing schoolwork and schoolwork, alone. Then you can reward yourself with a few minutes of social networking.

Active Learning

Have students conduct research about laws governing cell phone use and texting while driving. Have students see whether research into attention was used to craft or justify the laws. Consider having your students develop a public relations campaign about distracted driving that will use psychological principles to appeal to their peers. Students can also try the New York Times distracted driving simulation at www.nytimes.com/interactive/2009/07/19/technology/20090719-driving-game.html?_r=0.

ENGAGE

Enrichment

When people get so caught up in an experience that they miss out on obvious stimuli in the environment, they are said to be having a flow experience. Flow, a term coined by Mihalyi Csikszentmihalyi (chik-sent-me-high), involves being skilled at a challenging task that takes away our sense of self-consciousness and awareness of time and the presence of others around us.
TEACH

Teaching Tip
Have students speculate how selective attention is related to the evolutionary perspective. They can give examples of each of the following:

- If we had to attend to every stimulus in the environment, we might be hindered from action.
- However, if we miss important stimuli in the environment due to attention that is too selective, we may fall victim to all sorts of trouble—falls, car accidents, etc.

ENGAGE

Online Activities
Students may be interested in learning more about change blindness by visiting the website created by University of Illinois professor Daniel J. Simons, author of the book, The Invisible Gorilla. He and his team research attention issues, and they have created several famous videos that demonstrate our blindness to change. Visit www.simonslab.com.

Most European countries and American states now ban hand-held cell phones while driving (Rosenthal, 2009). Engineers are also devising ways to monitor drivers’ gaze and to direct their attention back to the road (Lee, 2009).

Selective Inattention
At the level of conscious awareness, we are “blind” to all but a tiny sliver of visual stimuli. Researchers demonstrated this inattentional blindness dramatically by showing people a 1-minute video in which images of three black-shirted men tossing a basketball were superimposed over the images of three white-shirted players (Neisser, 1979; Becklen & Cervone, 1983). The viewers’ supposed task was to press a key every time a black-shirted player passed the ball. Most focused their attention so completely on the game that they failed to notice a young woman carrying an umbrella saunter across the screen midway through the video (FIGURE 16.2). Seeing a replay of the video, viewers were astonished to see her (Mack & Rock, 2000). This inattentional blindness is a by-product of what we are really good at: focusing attention on some part of our environment.

In a repeat of the experiment, smart-aleck researchers Daniel Simons and Christopher Chabris (1999) sent a gorilla-suited assistant through the swirl of players. During its 5- to 9-second cameo appearance, the gorilla paused to thump its chest. Still, half the conscientious pass-counting viewers failed to see it. In another follow-up experiment, only 1 in 4 students engrossed in a cell-phone conversation while crossing a campus square noticed a clown-suited unicyclist in their midst (Hyman et al., 2010). (Most of those not on the phone did notice.) Attention is powerfully selective. Your conscious mind is in one place at a time.

Given that most people miss someone in a gorilla or clown suit while their attention is riveted elsewhere, imagine the fun that magicians can have by manipulating our selective attention. Misdirect people’s attention and they will miss the hand slipping into the pocket. “Every time you perform a magic trick, you’re engaging in experimental psychology,” says Teller, a magician and master of mind-messing methods (2009).

Magicians also exploit a form of inattentional blindness called change blindness. By selectively riveting our attention on their left hand’s dramatic act, we fail to notice changes made with their other hand. In laboratory experiments, viewers didn’t notice that, after a brief visual interruption, a big Coke bottle had disappeared, a railing had risen, or clothing color had changed (Chabris & Simons, 2010; Resnick et al., 1997). Focused on giving directions to a construction worker, two out of three people also failed to notice when he was replaced by another worker during a staged interruption (FIGURE 16.3). Out of sight, out of mind.
An equally astonishing form of inattention is choice blindness. At one Swedish supermarket, people tasted two jams, indicated their preference, and then tasted again their preferred jam and explained their preference. Fooled by trick jars (see FIGURE 16.4) most people didn’t notice that they were actually “retasting” their nonpreferred jam.

Some stimuli, however, are so powerful, so strikingly distinct, that we experience pop-out, as when we notice an angry face in a crowd. We don’t choose to attend to these stimuli; they draw our eye and demand our attention.

Our selective attention extends even into our sleep, as we will see.

Transduction

What three steps are basic to all our sensory systems?

Every second of every day, our sensory systems perform an amazing feat: They convert one form of energy into another. Vision processes light energy. Hearing processes sound waves. All our senses

- sense sensory stimulation, often using specialized receptor cells.
- transform that stimulation into neural impulses.
- deliver the neural information to our brain.

The process of converting one form of energy into another that your brain can use is called transduction. Later in this unit, we’ll focus on individual sensory systems. How do we see? Hear? Feel pain? Taste? Smell? Keep our balance? In each case, we’ll consider these three steps—receiving, transforming, and delivering the information to the brain. We’ll also see what psychophysics has discovered about the physical energy we can detect and its effects on our psychological experiences.

First, though, let’s explore some strengths and weaknesses in our ability to detect and interpret stimuli in the vast sea of energy around us.

Concept Connections

Relate choice blindness to implicit associations. Harvard researchers have been examining how our unconscious associations affect prejudice and discrimination. Have students take the implicit association test online: https://implicit.harvard.edu/implicit.

Online Activities

Several versions of the change and choice blindness experiments are available on social media sites such as YouTube. You can find videos by searching for “change blindness experiment” or “choice blindness experiment.” These videos may be used as a classroom demonstration of these phenomena or as videos for students to watch on their own, which you can then use as a starting point for classroom discussion.
As long ago as 1888, Joseph Jastrow speculated that lapses of attention, slight fatigue, and other psychological changes could cause fluctuations in the absolute threshold.

**ENGAGE**

**Enrichment**

Gustav Fechner (1801–1887) developed 3 methods of experimental measurement used to study sensory phenomenon:

- **Method of limits.** Begin with a minimal stimulus and increase it until the participant can perceive it. This method helps determine the “just noticeable difference.”
- **Method of right and wrong cases.** Present identical stimuli repeatedly—either single stimuli at the threshold or pairs of stimuli that are very similar. The participant responds yes if perceived or no if not perceived or different.
- **Method of adjustment.** Adjust a comparison stimulus until it appears identical to the standard stimulus. Every error is recorded and after many trials, the average error is computed. It, too, provides a measure of just noticeable difference.

**TEACH**

**Flip It**

Students can get additional help understanding signal detection theory by watching the Flip It Video: Signal Detection Theory on this topic.

**TEACH**

**Common Pitfalls**

Students may wonder why anyone cares about signal detection theory. The research in this area is especially important to fields where attention to detail amid environmental distractions is paramount, such as air traffic controllers, security screeners, law enforcement, and even ordinary car drivers.

**ENGAGE**

**Active Learning**

Have students place an alarm clock (or wristwatch) on a table in a quiet room. They should move away so that they can no longer hear the ticking, then gradually move toward the clock until they begin to hear the sound. This is the “momentary” threshold. If they remain in place, occasionally they won’t be able to hear the sound and will need to step forward to reach threshold. At other times the sound will get louder and they will be able to step back. This changing sensitivity indicates that the “absolute threshold” is anything but absolute.


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**Thresholds**

**16-4**

What are the absolute and difference thresholds, and do stimuli below the absolute threshold have any influence on us?

At this moment, you and I are being struck by X-rays and radio waves, ultraviolet and infrared light, and sound waves of very high and very low frequencies. To all of these we are blind and deaf. Other animals with differing needs detect a world that lies beyond our experience. Migrating birds stay on course aided by an internal magnetic compass. Bats and dolphins locate prey using sonar, bouncing echoing sound off objects. Bees navigate on cloudy days by detecting invisible (to us) polarized light.

The shades on our own senses are open just a crack, allowing us a restricted awareness of this vast sea of energy. But for our needs, this is enough.

**Absolute Thresholds**

To some kinds of stimuli we are exquisitely sensitive. Standing atop a mountain on an utterly dark, clear night, most of us could see a candle flame atop another mountain 30 miles away. We could feel the wing of a bee falling on our cheek. We could smell a single drop of perfume in a three-room apartment (Galanter, 1962).

German scientist and philosopher Gustav Fechner (1801–1887) studied our awareness of these faint stimuli and called them our absolute thresholds—the minimum stimulation necessary to detect a particular light, sound, pressure, taste, or odor 50 percent of the time. To test your absolute threshold for sounds, a hearing specialist would expose each of your ears to varying sound levels. For each tone, the test would define where half the time you could detect the sound and half the time you could not. That 50–50 point would define your absolute threshold.

Detecting a weak stimulus, or signal, depends not only on the signal’s strength (such as a hearing test tone) but also on our psychological state—our experience, expectations, motivation, and alertness. Signal detection theory predicts when we will detect weak signals (measured as our ratio of “hits” to “false alarms”) (FIGURE 16.5). Signal detection theorists seek to understand why people respond differently to the same stimuli (have you ever noticed that some teachers are much more likely than others to detect students texting during class?) and why the same person’s reactions vary as circumstances change. Frustrated parents will notice the faintest whimper from a newborn’s cradle while failing to notice louder, unimportant sounds. Lonely, anxious people at speed-dating events also respond with a low threshold and thus tend to be unselective in reaching out to potential dates (McClure et al., 2010).

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**Figure 16.5** Signal detection. What three factors will make it more likely that you correctly detect a text message?

1. The meaning and priority of the text are high.
2. You are anticipating a text.
3. You are checking your phone a lot.

**Figure 16.6** Absolute threshold. The minimum stimulation needed to detect a particular stimulus 50 percent of the time.
Stimuli you cannot detect 50 percent of the time are subliminal—below your absolute threshold (FIGURE 16.6). Under certain conditions, you can be affected by stimuli so weak that you don’t consciously notice them. An unnoticed image or word can reach your visual cortex and briefly prime your response to a later question. In a typical experiment, the image or word is quickly flashed, then replaced by a masking stimulus that interrupts the brain’s processing before conscious perception (Van den Bussche et al., 2009). For example, one experiment subliminally flashed either emotionally positive scenes (kittens, a romantic couple) or negative scenes (a werewolf, a dead body) an instant before participants viewed slides of people (Krosnick et al., 1992). The participants consciously perceived either scene as only a flash of light. Yet the people somehow knew if their image immediately followed an unperceived werewolf rather than an unperceived kitten. As other experiments confirm, we can evaluate a stimulus even when we are not aware of it—and even when we are unaware of our evaluation (Ferguson & Zayas, 2009).

How do we feel or respond to what we do not know and cannot describe? An imperceptibly brief stimulus often triggers a weak response that can be detected by brain scanning (Blankenburg et al., 2003; Haynes & Rees, 2005, 2006). Only when the stimulus triggers synchronized activity in several brain areas does it reach consciousness (Dehaene, 2009). (Blankenburg et al., 2003; Haynes & Rees, 2005, 2006). Only when the stimulus triggers synchronized activity in several brain areas does it reach consciousness (Dehaene, 2009). Once again we see the dual-track mind at work: unconscious processing before conscious perception (Van den Bussche et al., 2009). For example, one experiment subliminally flashed either emotionally positive scenes (kittens, a romantic couple) or negative scenes (a werewolf, a dead body) an instant before participants viewed slides of people (Krosnick et al., 1992). The participants consciously perceived either scene as only a flash of light. Yet the people somehow knew if their image immediately followed an unperceived werewolf rather than an unperceived kitten. As other experiments confirm, we can evaluate a stimulus even when we are not aware of it—and even when we are unaware of our evaluation (Ferguson & Zayas, 2009).

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To function effectively, we need absolute thresholds low enough to allow us to detect important sights, sounds, textures, tastes, and smells. We also need to detect small differences among stimuli. A musician must detect minute discrepancies when tuning an instrument. Students in the hallway must detect the sound of their friends’ voices amid all the other voices. Even after living two years in Scotland, sheep hear all sound alike to my ears. But not to those of ewes, which I have observed streaking, after shearing, directly to the fuss of their lamb amid the chorus of other distressed lambs.

**ENGAGE**

**Enrichment**

Anthony Pratkanis identified factors that contribute to the public’s beliefs regarding subliminal influence.

- Popular accounts of subliminal influence appeal to the “pop” psychology of the day.
- Popular accounts link subliminal influence to the issue of the day. Subliminal influence first emerged as a national concern after the Korean War when brainwashing and hypnotic suggestion captured the nation’s imagination in films such as *The Manchurian Candidate*.

- Many of the popular articles fail to report scientific evidence that is critical of claims for subliminal persuasion.
- Belief in subliminal persuasion may serve a need for many individuals. Subliminal persuasion takes on a supernatural “the devil made me do it” quality capable of explaining why Americans engage in irrational consumer behavior.

**Active Learning**

With federal takeover of airport screening as a result of the 9/11 attacks, accurate signal detection (like looking for suspicious bags, packages, or activities by passengers) by Transportation Safety Administration (TSA) employees remains an important concern. Contact a nearby TSA office or air traffic control office to ask if representatives from your class might interview a supervisor about the following issues in signal detection:

- What policies are in place that increase accurate signal detection?
- What training programs do you use to equip screeners to make accurate calls about stimuli?
- Do you offer incentives based on accurate performance? Why or why not?
- Does your office engage in periodic checks of accurate signal detection? What methods do you use to study this area?
Common Pitfalls

Some students may have heard that movie theaters in the 1950s used subliminal advertising to increase sales of popcorn and soda. They placed frames that said, “buy popcorn” and “buy Coke” within movies, which was supposed to encourage people to subliminally want to purchase concessions. This advertising ploy never happened. The source of the myth, James Vicary, actually lied about experiments he conducted at a New Jersey movie theater. His lie, however, led the Federal Communications Commission to ban so-called “subliminal advertising” in 1974 (Source: www.snopes.com).

Concept Connections

Although subliminal advertising may not work, priming does. If we are exposed to stimuli about a specific subject, we are more likely to recognize information about that subject in the environment. This phenomenon is related to context effects, which is discussed in more detail in Module 17.

Active Learning

Weber’s law can be applied to many situations. Robert Cialdini suggests having students imagine a man who wants to buy a 3-piece suit and a sweater. If you were the salesperson, which should you show him first in order to get him to spend the most money? You might think it best to sell the sweater first. Having spent a lot on a suit, the customer might be reluctant to spend more on a sweater. However, sales motivation analysts suggest the opposite. Sell the suit first because the additional cost of the sweater will not be so readily noticed. If the man has just paid $300 for a suit, an additional $75 for a sweater will not seem excessive. The same applies to other accessories, such as a shirt or shoes. As a rule, people will almost always pay more for accessories if they buy them after, rather than before, a more expensive purchase.

Thinking Critically About

Can Subliminal Messages Control Our Behavior?

Hoping to penetrate our unconscious, entrepreneurs offer audio and video programs to help us lose weight, stop smoking, or improve our memories. Soothing ocean sounds may mask messages we cannot consciously hear: “I am thin!”; “Smoke tastes bad”; or “I do well on tests—I have total recall of information.” Such claims make two assumptions: (1) We can unconsciously sense subliminal (literally, “below threshold”) stimuli; (2) Without our awareness, these stimuli have extraordinary persuasive powers. Can we? Do they?

As we have seen, subliminal sensation is a fact. Remember that an “absolute” threshold is merely the point at which we can detect a stimulus half the time. At or slightly below this threshold, we will still detect the stimulus some of the time. But does this mean that claims of subliminal persuasion are also facts? The near-consensus among researchers is No. The laboratory research reveals a subtle, fleeting effect. Priming thirsty people with the subliminal word thirst might therefore, for a moment, make a thirst-quenching beverage ad more persuasive (Strahan et al., 2002). Likewise, priming thirsty people with Lipton Iced Tea may increase their choosing the primed brand (Kamman et al., 2000; Volberg et al. 2011; Vervliet et al., 2011). But the subliminal-message hucksters claim something different: a powerful, enduring effect on behavior.

To test whether subliminal recordings have the enduring effect researchers randomly assigned university students to listen daily for 5 weeks to commercial subliminal messages claiming to improve either self-esteem or memory (Greenwald et al., 1991, 1992). But the researchers played a practical joke and switched half the labels. Some students who thought they were receiving affirmations of self-esteem were actually hearing the memory-enhancement message. Others got the self-esteem message but thought their memory was being recharged.

Were the recordings effective? Students’ test scores for self-esteem and memory, taken before and after the 5 weeks, revealed no effects. Yet the students perceived themselves receiving the benefits they expected. Those who thought they had heard a memory recording believed their memories had improved. Those who thought they had heard a self-esteem recording believed their self-esteem had grown. (Reading this research, one hears echoes of the testimonies that ooze from ads for such products. Some customers, having bought what is not supposed to be heard [and having indeed not heard it] offer testimonials like, “I really know that your recordings were invaluable in reprogramming my mind.”)

Over a decade, Greenwald conducted 16 double-blind experiments evaluating subliminal self-help recordings. His results were uniform: Not one of the recordings helped more than a placebo (Greenwald, 1990). And placebo, you may remember, work only because we believe they will work.

The difference threshold (or the just noticeable difference [jnd]) is the minimum difference a person can detect between any two stimuli half the time. That difference threshold increases with the size of the stimulus. Thus, if you add 1 ounce to a 10-ounce weight, you will detect the difference; add 1 ounce to a 100-ounce weight and you probably will not.

In the nineteenth century, Ernst Weber noted something so simple and so widely applicable that we still refer to it as Weber’s law. This law states that for an average person to perceive a difference, two stimuli must differ by a constant minimum percentage (not a constant number) of the larger of the two.

Active Learning

To apply Weber’s law, students need 3 quarters, 2 envelopes, and a pair of shoes. Have them place one quarter in one envelope and the remaining 2 quarters in the other. Lifting each envelope, they can easily determine which is heavier. Now have them put each envelope in a shoe. When they lift the shoes, one at a time, the weight difference will be imperceptible.


constant amount. The exact proportion varies, depending on the stimulus. Two lights, for example, must differ in intensity by 8 percent. Two objects must differ in weight by 2 percent. And two tones must differ in frequency by only 0.3 percent (Teghtsoonian, 1971). For example, to be perceptibly different, a 50-ounce weight must differ from another by about an ounce, a 100-ounce weight by about 2 ounces.

Sensory Adaptation

16-9 What is the function of sensory adaptation?

Entering your neighbors’ living room, you smell a musty odor. You wonder how they can stand it, but within minutes you no longer notice it. Sensory adaptation has come to your rescue. When we are constantly exposed to a stimulus that does not change, we become less aware of it because our nerve cells fire less frequently. (To experience sensory adaptation, move your watch up your wrist an inch: You will feel it—but only for a few moments.) Why, then, if we stare at an object without blinking, does it not vanish from sight? Because, unnoticed by us, our eyes are always moving. This continual shifting from one spot to another ensures that stimulation on the eye’s receptors continually changes (FIGURE 16.7). What if we actually could stop our eyes from moving? Would sights seem to vanish, as odors do? To find out, psychologists have devised ingenious instruments that maintain a constant image on the eye’s inner surface. Imagine that we have fitted a volunteer, Mary, with one of these instruments—a miniature projector mounted on a contact lens (FIGURE 16.8a on the next page). When Mary’s eye moves, the image from the projector moves as well. So everywhere that Mary looks, the scene is sure to go. If we project images through this instrument, what will Mary see? At first, she will see the complete image. But within a few seconds, as her sensory system begins to fatigue, things get weird. Bit by bit, the image vanishes, only to reappear and then disappear—often in fragments (Figure 16.8b). Although sensory adaptation reduces our sensitivity, it offers an important benefit: freedom to focus on informative changes in our environment without being distracted by background chatter. Stinky or heavily perfumed classmates don’t notice their odor because, like you and me, they adapt to what’s constant and detect only change. Our sensory receptors

**Difference threshold** the minimum difference between two stimuli required for detection—50 percent of the time. We experience the difference threshold as a just noticeable difference (jnd).

**Weber’s law** the principle that, to be perceived as different, two stimuli must differ by a constant minimum percentage (rather than a constant amount). Sensory adaptation diminished sensitivity as a consequence of constant stimulation.

Figure 16.7 The jumpy eye. Our gaze jumps from one spot to another every third of a second or so, as eye-tracking equipment illustrated in this photograph of Edinburgh’s Princes Street Gardens (Henderson, 2007). The circles represent fixations, and the numbers indicate the time of fixation in milliseconds (100 milliseconds = three-fifths of a second).

**ENGAGE**

Active Learning

Adaptation to the taste of one substance can affect the taste of another, either decreasing or increasing our sensitivity to it. Using 3 glasses of water (one mixed with salt, one mixed with vinegar, and one fresh), have a student volunteer come to the front of the classroom. Have the student taste the saltwater and hold it in his or her mouth for a time; it will gradually taste less salty. If the student then takes a glass of fresh water, it will taste bitter or sour. Have another student volunteer come to the front of the room and hold a mouthful of vinegar and water until it becomes less bitter. The glass of fresh water will taste sweet. The variability in the taste of ordinary tap water following adaptation to various substances will surprise many students.

Several concepts in this module may be difficult to understand and are often confused. To assess whether students understand these concepts, ask them to give examples and provide definitions or compare and contrast the following:

- Top-down vs. bottom-up processing
- Absolute vs. difference thresholds

We perceive the world not exactly as it is, but as it is useful for us to perceive it. Our sensitivity to changing stimulation helps explain television's attention-grabbing power: Cuts, edits, zooms, pans, sudden noises—all demand attention. The phenomenon is irresistible even to TV researchers. One noted that even during interesting conversations, “I cannot for the life of me stop from periodically glancing over to the screen” (Tannenbaum, 2002).

Sensory adaptation even influences our perceptions of emotions. By creating a 50-50 morphed blend of an angry and a scared face, researchers showed that our visual system adapts to a static facial expression by becoming less responsive to it (Butler et al., 2008). Sensory adaptation and sensory thresholds are important ingredients in our perceptions of the world around us. Much of what we perceive comes not just from what’s “out there” but also from what’s behind our eyes and between our ears.

**Close & Assess**

**Exit Assessment**

Can you recall a recent time when, your attention focused on one thing, you were oblivious to something else (perhaps to pain, to someone’s approach, or to background music)?

**Test Yourself**

Explain how Heather Sellers’ experience of prosopagnosia illustrates the difference between sensation and perception.

Answers to the Test Yourself questions can be found in Appendix E at the end of the book.
Module 16 Review

16-1 What are sensation and perception? What do we mean by bottom-up processing and top-down processing?

- Sensation is the process by which our sensory receptors and nervous system receive and represent stimulus energies from our environment. Perception is the process of organizing and interpreting this information, enabling recognition of meaningful events. Sensation and perception are actually parts of one continuous process.
- Bottom-up processing is sensory analysis that begins at the entry level, with information flowing from the sensory receptors to the brain. Top-down processing is information processing guided by high-level mental processes, as when we construct perceptions by filtering information through our experience and expectations.

16-2 How much information do we consciously attend to at once?

- We selectively attend to, and process, a very limited portion of incoming information, blocking out much and often shifting the spotlight of our attention from one thing to another.
- Focused intently on one task, we often display inattentional blindness (including change blindness) to other events and changes around us.

16-3 What three steps are basic to all our sensory systems?

- Our senses (1) receive sensory stimulation (often using specialized receptor cells); (2) transform that stimulation into neural impulses; and (3) deliver the neural information to the brain. Transduction is the process of converting one form of energy into another.

Multiple-Choice Questions

1. What occurs when experiences influence our interpretation of data?
   a. Selective attention
   b. Transduction
   c. Bottom-up processing
   d. Top-down processing
   e. Signal detection theory

2. What principle states that to be perceived as different, two stimuli must differ by a minimum percentage rather than a constant amount?
   a. Absolute threshold
   b. Different threshold
   c. Signal detection theory
   d. Priming
   e. Weber’s law

Researchers in psychophysics study the relationships between stimuli’s physical characteristics and our psychological experience of them.

16-4 What are the absolute and difference thresholds, and do stimuli below the absolute threshold have any influence on us?

- Our absolute threshold for any stimulus is the minimum stimulation necessary for us to be consciously aware of it 50 percent of the time. Signal detection theory predicts how and when we will detect a faint stimulus amid background noise. Individual absolute thresholds vary, depending on the strength of the signal and also on our experience, expectations, motivation, and alertness.
- Our difference threshold (also called just noticeable difference, or jnd) is the difference we can discern between two stimuli 50 percent of the time. Weber’s law states that two stimuli must differ by a constant percentage (not a constant amount) to be perceived as different.
- Priming shows that we can process some information from stimuli below our absolute threshold for conscious awareness. But the effect is too fleeting to enable people to exploit us with subliminal messages.

16-5 What is the function of sensory adaptation?

- Sensory adaptation (our diminished sensitivity to constant or routine odors, sights, sounds, and touches) focuses our attention on informative changes in our environment.

Module 16 Review

MyersAP_SE_2e_Mod16_B.indd   161 1/21/14   9:32 AM

MyersPsyAP_TE_2e_U04.indd   161 2/20/14   8:09 AM
3. What do we call the conversion of stimulus energies, like sights and sounds, into neural impulses?
   a. Transduction
   b. Perception
   c. Priming
   d. Signal detection theory
   e. Threshold

4. Natalia is washing her hands and adjusts the faucet handle until the water feels just slightly hotter than it did before. Natalia’s adjustment until she feels a difference is an example of
   a. a subliminal stimulus.
   b. an absolute threshold.
   c. a difference threshold.
   d. signal detection.
   e. Weber’s law.

5. Tyshane went swimming with friends who did not want to get into the pool because the water felt cold. Tyshane jumped in and after a few minutes declared, “It was cold when I first got in, but now my body is used to it. Come on in!” Tyshane’s body became accustomed to the water due to
   a. perceptual set.
   b. absolute threshold.
   c. difference threshold.
   d. selective attention.
   e. sensory adaptation.

Practice FRQs

1. Explain how bottom-up and top-down processes work together to help us decipher the world around us.
   Answer
   1 point: Bottom-up processing starts at the sensory receptors and works up to higher levels of processing.
   1 point: Top-down processing constructs perceptions from the sensory input by drawing on our experience and expectations.

5. Marisol is planning a ski trip for spring break. Define absolute threshold and difference threshold, and explain how each one might play a role in her perception of the winter weather she will experience.
   (4 points)

3. a  5. e

4. c
Module 17
Influences on Perception

Module Learning Objectives

17-1 Explain how our expectations, contexts, emotions, and motivation influence our perceptions.
17-2 List the claims of ESP, and discuss the conclusions of most research psychologists after putting these claims to the test.

Perceptual Set

17-1 How do our expectations, contexts, emotions, and motivation influence our perceptions?

As everyone knows, to see is to believe. As we less fully appreciate, to believe is to see. Through experience, we come to expect certain results. Those expectations may give us a perceptual set, a set of mental tendencies and assumptions that greatly affects (top-down) what we perceive. Perceptual set can influence what we hear, taste, feel, and see. Consider: Is the image in the center picture of Figure 17.1 a young woman’s profile or an old woman? What we see in such a drawing can be influenced by first looking at either of the two unambiguous versions (Boring, 1930).

Everyday examples of perceptual set abound. In 1972, a British newspaper published unretouched photographs of a “monster” in Scotland’s Loch Ness—“the most amazing

Discussion Starter

Use the Module 17 Fact or Falsehood? student activity from the TRM to introduce the concepts from this module.

Teaching Tip

Ask your class to shout out the answers to the following questions. “What do these letters spell?” (Write folk on the board.) “How about these?” (Write croak.) “And what do these letters spell?” (Write soak.) “What do we call the white of an egg?” Students will respond “yolk” even though the answer is “egg white.”

This activity demonstrates the power of perceptual set. Students get into a pattern of spelling the word in a particular way, so when one homophone word is introduced, they will spell it consistently with the pattern.

Concept Connections

Perceptual set is similar to priming. What we expect to see is often influenced by what is around us.
**ENGAGE**

Active Learning

Have students create their own perceptual set studies by packaging generic foods and drinks in name-brand packaging. They can then do taste tests with their friends or family to see whether the packaging matters. How do the people judge the products: same, better, or worse? Have students discuss how perceptual set influences people’s perceptions of the products.

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**TEACH**

Concept Connections

Schemas are an important concept in psychology. Swiss psychologist Jean Piaget developed the idea of schemas to describe the ways in which we conceptualize the world. These schemas help explain why we are vulnerable to our perceptual sets. Schemas are further discussed in Unit IX.

Perceptual set similarly affects taste. One experiment invited some bar patrons to sample free beer (Lee et al., 2006). When researchers added a few drops of vinegar to a brand-name beer, the tasters preferred it—unless they had been told they were drinking vinegar-laced beer. Then they expected, and usually experienced, a worse taste. In another experiment, preschool children, by a 6-to-1 margin, thought french fries tasted better when served in a McDonald’s bag rather than a plain white bag (Robinson et al., 2007).

What determines our perceptual set? As Module 47 will explain, through experience we form concepts, or schemas, that organize and allow us to interpret unfamiliar information. Our pre-existing schemas for old women and young women, for monsters and tree limbs, all influence how we interpret ambiguous sensations with top-down processing.

In everyday life, stereotypes about gender (another instance of perceptual set) can color perception. Without the obvious cues of pink or blue, people will struggle over whether to call the new baby “he” or “she.” But told an infant is “David,” people (especially children) may perceive “him” as bigger and stronger than if the same infant is called “Diana” (Stern & Karraker, 1989). Some differences, it seems, exist merely in the eyes of their beholders.

**Context Effects**

A given stimulus may trigger radically different perceptions, partly because of our differing perceptual set, but also because of the immediate context. Some examples:
Diversity Connections

The drawing at the top of p. 165 is an excellent example of how culture influences perception. Most Westerners have no trouble interpreting the scene of people sitting inside a dwelling. They do not confuse the window with a box on the woman’s head. However, those from other cultures who do not share the same perceptual sets perceive the scene differently. Help students see the perspective of others with this picture.

Teaching Tip

Use the figures throughout the unit to demonstrate to students these perceptual concepts. Have students find their own examples of these and create a library of visual illusions to use with students. You might direct them to the website http://dragon.uml.edu/psych/.

Enrichment

Research on context shows that situations can have a powerful effect on behavior:

- Studying should not occur while lying in bed. Students who do this often associate studying with sleeping because they study where they sleep. For effective studying, a designated place should be created where all the necessary supplies are available.

- Sleep researchers assisting those suffering from insomnia suggest designating the bed for sleeping only and not for watching TV or reading. People may come to associate the bed with those other activities rather than with sleeping, which can hinder their ability to fall asleep easily.
Emotion and Motivation

Perceptions are influenced, top-down, not only by our expectations and by the context, but also by our emotions and motivation.

Hearing sad rather than happy music can predispose people to perceive a sad meaning in spoken homophonic words—mourning rather than morning, die rather than dye, pain rather than pane (Halberstadt et al., 1995).

Researchers (Proffitt, 2006a,b; Schnall et al., 2008) have demonstrated the power of emotions with other clever experiments showing that

- walking destinations look farther away to those who have been fatigued by prior exercise.
- a hill looks steeper to those who are wearing a heavy backpack or have just been exposed to sad, heavy classical music rather than light, bouncy music. As with so many of life’s challenges, a hill also seems less steep to those with a friend beside them.
- a target seems farther away to those throwing a heavy rather than a light object at it. Even a softball appears bigger when you are hitting well, observed other researchers, after asking players to choose a circle the size of the ball they had just hit well or poorly (Witt & Proffitt, 2005). When angry, people more often perceive neutral objects as guns (Bauman & DeSteno, 2010).

Motives also matter. Desired objects, such as a water bottle when thirsty, seem closer (Balcetis & Dunning, 2010). This perceptual bias energizes our going for it. Our motives also direct our perception of ambiguous images.

Emotions color our social perceptions, too. Spouses who feel loved and appreciated perceive less threat in stressful marital events—“He’s just having a bad day” (Murray et al., 2003). Professional referees, if told a soccer team has a history of aggressive behavior, will assign more penalty cards after watching videotaped fouls (Jones et al., 2002).

* * *

Emotion and motivation clearly influence how we perceive sensations. But what to make of extrasensory perception, which claims that perception can occur apart from sensory input? For more on that question, see Thinking Critically About: ESP—Perception Without Sensation?

Before You Move On

ASK YOURSELF
- Can you recall a time when your expectations have predisposed how you perceived a person (or group of people)?

TEST YOURSELF
- What type of evidence shows that, indeed, “there is more to perception than meets the senses”?

Answers to the Test Yourself questions can be found in Appendix E at the end of the book.
Thinking Critically About

ESP—Perception Without Sensation?

What are the claims of ESP, and what have most research psychologists concluded after putting these claims to the test?

Without sensory input, are we capable of extrasensory perception (ESP)? Are there indeed people—who can read minds, see through walls, or forestall the future? Nearly half of Americans believe there are (AP, 2007; Moore, 2005).

The most testable and, for this unit, most relevant parapsychological concepts are

• telepathy: mind-to-mind communication.
• clairvoyance: perceiving remote events, such as a house on fire in another state.
• precognition: perceiving future events, such as an unexpected death in the next month.

Closely linked is psychokinesis, or “mind over matter,” such as levitating a table or influencing the roll of a die. (The claim is illustrated by the wry request, “Will all those who believe in psychokinesis please raise my hand?”)

If ESP is real, we would need to overturn the scientific understanding that we are creatures whose minds are tied to our physical brains and whose perceptual experiences of the world are built of sensations. Sometimes new evidence does overturn our scientific preconceptions. Science, as we will see throughout this book, offers us various surprises—about the extent of the unconscious mind, about the effects of emotions on health, about what heals and what doesn’t, and much more.

Most research psychologists and scientists—including 96 percent of the scientists in the U.S. National Academy of Sciences—are skeptical that paranormal phenomena exist (McConnell, 1991). But reputable universities in many locations, including Great Britain, the Netherlands, and Australia, have added faculty chairs or research units in parapsychology (Turpin, 2005). These researchers perform scientific experiments searching for possible ESP and other paranormal phenomena. Before seeing how parapsychologists do research on ESP, let’s consider some popular beliefs.

PREMONITIONS OR PRETENSIONS?

Can psychics see into the future? Although one might wish for a psychic stock forecaster, the failed forecasts of “leading psychics” reveal meager accuracy. During the 1990s, the tabloid psychics were all wrong in predicting surprising events. (Madonna did not become a gospel singer, the Statue of Liberty did not lose both its arms in a terrorist blast, Queen Elizabeth did not abdicate her throne to enter a convent.) And the new-century psychics have missed the big-news events. Where were the psychics on 9/11, or on 9/10 when we needed them? Why, despite a $50 million reward offered, could none of them help locate terrorist Osama bin Laden after the horror of 9/11, or stop forward to predict the impeding stock crashes in 2008?

In 30 years, unusual predictions have almost never come true, and psychics have virtually never anticipated any of the year’s headline events (Smory, 2004, 2006). In 2010, when a mine collapse trapped 33 miners, the Chilean government reportedly consulted four psychics. Their verdict? “They’re all dead” (Kraul, 2010). But 69 days later, all 33 were rescued.

Moreover, the hundreds of psychic visions offered to police departments have been no more accurate than guesses made by others (Nekroll, 1994, 2005; Radford, 2011; Reiser, 1982). But their sheer volume does increase the odds of an occasional correct guess, which psychics can then report to the media. Police departments are wise to all this. When researchers asked the police departments of America’s 50 largest cities whether they ever had used psychics, 65 percent said no (Sweat & Durum, 1993). Of those that had, not one had found them helpful. Vague predictions can also later be interpreted “retrofitted.”

EXTRASENSORY PERCEPTION (ESP): the controversial claim that perception can occur apart from sensory input; includes telepathy, clairvoyance, and precognition.

PARAPSYCHOLOGY: the study of paranormal phenomena, including ESP and psychokinesis.
ENGAGE

Online Activities

The following websites offer information about scientific testing of psychic phenomena:
- The James Randi Educational Foundation homepage at www.randi.org.

After searching these sites, have students address the following questions:
- Why are psychics generally unwilling to be scientifically tested?
- Do you think paranormal phenomena is a worthy scientific subject to study? Why or why not?

Use Teacher Demonstration: ESP Trick—Precognition (Playing Card Trick) from the TRM to help underline the necessity for rigid experimental control in evaluating ESP claims.

TEACH

Concept Connections

Remind students of the following concepts from scientific thinking in Unit II, especially when considering ESP and other paranormal phenomena:
- Correlation does not mean causation. Just because events occur together does not mean that they cause each other.
- Confirmation bias occurs when we only look for evidence that supports our beliefs and ignore evidence that refutes them. Many people believe in parapsychology because they rely only on the evidence that supports their beliefs.

Use Teacher Demonstration: ESP Trick—Precognition (Newspaper Article Trick) from the TRM to demonstrate a simple—yet doctorbed—newspaper article to demonstrate precognitive abilities.

Thinking Critically About (continued)

to match events that provide a perceptual set for "understanding" them. Nostradamus, a sixteenth-century French psychic, explained in an unguarded moment that his ambiguous prophecy "could not possibly be understood until they were interpreted after the event and by it."

"Are the spontaneous "visions" of everyday people any more accurate? Do dreams, for example, forecast the future, as people from both Eastern and Western cultures tend to believe—making some people more reluctant to fly after dreaming of a plane crash (Morewedge & Norton, 2009)? Or do they only seem to do so when we recall or reconstruct them in light of what has already happened? Two Harvard psychologists tested the prophetic power of dreams after superhero aviator Charles Lindbergh's baby son was kidnapped and murdered in 1932, but before the body was discovered (Murray & Wheeler, 1937) When invited to report their dreams about the child, 1300 visionaries submitted dream reports. How many accurately envisioned the child dead? Five percent. And how many also correctly anticipated the body's location—buried among trees? Only 4 of the 1300. Although this number was surely no better than chance, to those 4 dreamers the accuracy of their apparition precognitions must have seemed uncanny."

Given the billions of events in the world each day, and given enough days, some stunning coincidences are sure to occur. By one careful estimate, chance alone would predict that more than a thousand times a day someone on Earth will think of another person and then within the next five minutes will learn of that person's death (Charpak & Broch, 2004). Thus, when explaining an astonishing event, we should "give chance a chance" (Järelldt, 2009). With enough time and people, the improbable becomes inevitable.

"To be sure of hitting the target, shoot first and call whatever you hit the target." - Writer-Artist Ashleagh Brilliant, 1933

"A person who takes a hit is sometimes right." - Lassie, 1955

PUTTING ESP TO EXPERIMENTAL TEST

When faced with claims of mind reading or out-of-body travel or communication with the dead, how can we separate bizarre ideas from those that sound strange but are true? At the heart of science is a simple answer: Test them to see if they work.

This scientific attitude has led both believers and skeptics to agree that what parapsychology needs is a reproducible phenomenon and a theory to explain it. Parapsychologist Rhea White (1998) spoke for many in saying that "the image of parapsychology that comes to my mind, based on nearly 44 years in the field, is that of a small airplane [that] has been perpetually taxiing down the runway of the Empirical Science Airport since 1882. . . its movement punctuated occasionally by lifting a few feet off the ground only to bump back down on the tarmac once again. It has never taken off for any sustained flight."

How might we test ESP claims in a controlled, reproducible experiment? An experiment differs from a staged demonstration. In the laboratory, the experimenter controls what the "psychic" sees and hears. On stage, the psychic controls what the audience sees and hears.

The search for a valid and reliable test of ESP has resulted in thousands of experiments. After digesting data from 50 such studies, parapsychologist Lance Storm and his colleagues (2010a,b) concluded that, given participants with experience or belief in ESP, there is "consistent and reliable" parapsychological evidence. Psychologist Ray Hyman (2010), who has been scrutinizing parapsychological research since 1957, replies that if this is the best evidence, it fails to impress: "Parapsychology will achieve scientific acceptability only when it provides a positive theory with . . . independently replicable evidence. This is something it has yet to achieve after more than a century."

Daryl Bem (2011), a respected social psychologist, has been a skeptic of stage psychics: he once quipped that "a psychic is an actor playing the role of a psychic" (1984). Yet he has reignited hopes for replicable evidence with nine experiments that seemed to show people anticipating future events. In one,
Active Learning

Have students create their own experimental conditions under which they would like to test ESP. Use this activity as a check of their knowledge of research methodology learned from

Unit II. Use any of the following simple ESP tests from the TRM:

- Teacher Demonstration: ESP Trick—Clairvoyance
- Teacher Demonstration: ESP Trick—Mental Telepathy (Gray Elephant in Denmark Trick)
- Teacher Demonstration: ESP Trick—Mental Telepathy (Telephone Book Trick)

CLOSE & ASSESS

Exit Assessment

Provide students with the following scenario (or a similar one of your own choosing):

You are enjoying dinner with your family at a local restaurant. A large group of people, both male and female, enters the restaurant singing and talking loudly. The people continue to speak and sing loudly throughout their time in the restaurant. How do you perceive this situation and explain this group’s behavior? Use your knowledge of expectations/set, context, emotions, and motivations to craft your answer.

Use students’ explanations to determine how well they understand the concepts in this module.

Before You Move On

ASK YOURSELF

- Have you ever had what felt like an ESP experience?
- Can you think of an explanation other than ESP for that experience?

TEST YOURSELF

- What is the field of study that researches claims of extrasensory perception (ESP)?
- Answers to the Test Yourself questions can be found in Appendix E at the end of the book.

Influences on Perception
Module 17 Review

1. How do our expectations, contexts, emotions, and motivation influence our perceptions?

- **Perceptual set** is a mental predisposition that functions as a lens through which we perceive the world.
- Our learned concepts (schemas) prime us to organize and interpret ambiguous stimuli in certain ways.
- Our physical and emotional context, as well as our motivation, can create expectations and color our interpretation of events and behaviors.

2. What are the claims of ESP, and what have most research psychologists concluded after putting these claims to the test?

- Parapsychology is the study of paranormal phenomena, including extrasensory perception (ESP) and psychokinesis.
- The three most testable forms of ESP are telepathy (mind-to-mind communication), clairvoyance (perceiving remote events), and precognition (perceiving future events).
- Skeptics argue that (1) to believe in ESP, you must believe the brain is capable of perceiving without sensory input, and (2) researchers have been unable to replicate ESP phenomena under controlled conditions.

3. Which of the following is produced by perceptual set?

a. Not noticing that the songs change in a restaurant
b. Noticing a difference in the weight of a friend from one week to the next
c. Moving an arm quickly so that a mosquito flies away
d. Surprise at hearing an Oklahoma cowboy speak with a British accent
e. Not noticing a watch on your wrist as the day goes on

Multiple-Choice Questions

1. What do we call a mental predisposition that influences our interpretation of a stimulus?

2. Kimberly tells her brother to put on a suit on a warm summer day. Kimberly’s brother knows to put on a swimsuit instead of a business suit because of
   a. context   b. ESP   c. precognition   d. bottom-up processing   e. clairvoyance

3. Which of the following is produced by perceptual set?
   a. Not noticing that the songs change in a restaurant
   b. Noticing a difference in the weight of a friend from one week to the next
   c. Moving an arm quickly so that a mosquito flies away
   d. Surprise at hearing an Oklahoma cowboy speak with a British accent
   e. Not noticing a watch on your wrist as the day goes on

Answer to Practice FRQ 2

1 point: Context effects: Environmental factors can influence perception. For example, a tall basketball player might look short when standing next to a much taller player.

1 point: Emotion: Mood can influence perception. For example, happy or sad music can alter one’s perception of ambiguous words and scenes.

1 point: Motivation: Motivation can influence perception. For example, a water bottle can seem closer when one is thirsty.

1 point: Telepathy: Martha would be able to use mind-to-mind communication; that is, she is able to read someone’s mind.

1 point: Clairvoyance: Martha would be able to perceive things happening at a distance; that is, a cousin who lives in another state just burnt her hand on the oven, and Martha feels it.

1 point: Precognition: Martha would be able to see future events happen; that is, she knows a pop quiz will take place next week.

1 point: There has never been a conclusive scientific demonstration of extrasensory ability.

3 points: How can context effects, emotions, and motivation trigger different perceptions of a single stimulus?
Module 18

Vision

Module Learning Objectives

18-1 Describe the characteristics of visible light, and explain the process by which the eye transforms light energy into neural messages.

18-2 Describe how the eye and brain process visual information.

18-3 Discuss the theories that help us understand color vision.

What is the energy that we see as visible light, and how does the eye transform light energy into neural messages?

Our eyes receive light energy and transduce (transform) it into neural messages that our brain then processes into what we consciously see. How does such a taken-for-granted yet remarkable thing happen?

The Stimulus Input: Light Energy

When you look at a bright red tulip, what strikes your eyes is not particles of the color red but pulses of electromagnetic energy that your visual system perceives as red. What we see as visible light is but a thin slice of the whole spectrum of electromagnetic energy, ranging from imperceptibly short gamma waves to the long waves of radio transmission (Figure 18.1). Other organisms are sensitive to differing portions of the spectrum. Bees, for instance, cannot see what we perceive as red but can see ultraviolet light.

Two physical characteristics of light help determine our sensory experience of them. Light's wavelength—the distance from one wave peak to the next—explains why we see different colors. Wavelength and amplitude determine the relationship between colors and wavelength.

The wavelengths we see: What we see as light is only a tiny slice of a wide spectrum of electromagnetic energy, which ranges from gamma rays as short as the diameter of an atom to radio waves over a mile long. The wavelengths visible to the human eye (shown enlarged) extend from the shorter waves of blue-violet light to the longer waves of red light.

Interdisciplinary Connections

Teach

Have students draw, with the appropriate colored crayon, what the different wavelengths of light would look like. For instance, a bright red color would have a long wavelength, one with a great (tall) amplitude, whereas a dull blue color would have a short wavelength with a small (short) amplitude. Have them consult a physics textbook or search online for help with the colors between red and blue. Students with learning difficulties might appreciate this more tactile approach to understanding the relationship between colors and wavelength.

Engage

Online Activities

Vision Science is a site that provides recent research and activities related to human and animal visual systems. Use the following website to enhance students' understanding of our visual system: Vision Science at http://visionscience.com.
Vision and audition use similar terms to discuss the different stimuli that are processed by our visual and auditory systems. This is because both visual and auditory stimuli work in waves, so the characteristics of waves are similar for both light and sound. (For more on sound waves, see Module 20.)

- **Wavelength** determines the quality of the waves (for vision, color; for sound, pitch)
- **Amplitude** determines the intensity of the waves (for vision, brightness; for sound, loudness)

### Interdisciplinary Connections

Invitation your school’s art or photography teacher to explain how a camera is similar to the eye. Cameras use the eye as a model for how much light to let in to create a correct photograph of a given image or situation. Have the teacher cover any of the following topics:

- Why certain film is important to use for different situations and images
- Why a flash is important and when it should be used
- Creative ways photographers use the camera’s features to take interesting pictures

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**Common Pitfalls**

The word accommodation means different things in different contexts. For this unit, accommodation means the ways in which the muscles of the eye change the shape of the lens to focus light onto the retina. In Unit IX, accommodation means the ways in which we change our schemas to incorporate new information we learn.
Eventually, the answer became clear: The retina doesn’t “see” a whole image. Rather, its millions of receptor cells convert particles of light energy into neural impulses and forward those to the brain. Then, the impulses are reassembled into a perceived, upright-seeming image.

The Retina

If you could follow a single light-energy particle into your eye, you would first make your way through the retina’s outer layer of cells to its buried receptor cells, the rods and cones (FIGURE 18.4). There, you would see the light energy trigger chemical changes that would spark neural signals, activating nearby bipolar cells. The bipolar cells in turn would activate the neighboring ganglion cells, whose axons twine together like the strands of a rope to form the optic nerve. That nerve will carry the information to your brain, where your thalamus stands ready to distribute the information. The optic nerve can send nearly 1 million messages at once through its nearly 1 million ganglion fibers. (The auditory nerve, which enables hearing, carries much less information through its mere 30,000 fibers.) We pay a small price for this eye-to-brain highway. Where the optic nerve leaves the eye, there are no receptor cells—creating a blind spot (FIGURE 18.5 on the next page). Close one eye and you won’t see a black hole, however. Without seeking your approval, your brain fills in the hole.

Rods and cones differ in where they’re found and in what they do (TABLE 18.1 on the next page). Cones cluster in and around the fovea, the retina’s area of central focus (see Figure 18.3). Many have their own hotline to the brain: Each one transmits to a single bipolar cell. The bipolar cells in turn activate the ganglion cells, the axons of which converge to form the optic nerve. That nerve will carry the information to the visual cortex (via the thalamus) in the brain.

Rods have no such hotline; they share bipolar cells with other rods, sending combined messages. To experience this rod-cone difference in sensitivity to details, pick a word in this sentence and stare directly at it, focusing its image on the cones in your fovea. Notice that rods’ retinal receptors that detect black, white, and gray; necessary for peripheral and twilight vision, when cones don’t respond. Cones retinal receptor cells that are concentrated near the center of the retina and that function in daylight or in well-lit conditions. The cones detect fine detail and give rise to color sensations. Optic nerve the nerve that carries neural impulses from the eye to the brain. Blind spot the point at which the optic nerve leaves the eye, creating a “blind” spot because no receptor cells are located there. Fovea the central focal point in the retina, around which the eye’s cones cluster.

ENGAGE

Active Learning

Have students test their foveal vision in the dark as a homework project. Have them go in their backyards or in a darkened room (with light only from ambient sources) and try to focus their central vision on an object in the environment. They should reflect on how detailed the object appears. Then, have them look at the image in their peripheral vision, focusing their foveal vision just to the side of the object they want to see. They should note that the object becomes clearer and more detailed when they don’t look at it directly, because in dim light the cones in the fovea are not activated but the rods in the periphery are.
Engage

Active Learning

Extend the text’s blind-spot activity by having students notice what exactly fills the space where the blind spot is. The space is actually white, not gray or black as one would expect. Students can even draw a line around the car. This time they will notice the line continues as the brain creates what fills the blind spot based on the surrounding stimuli.

Engage

Enrichment

By deliberately aiming the blind spot, one can block out any appropriately sized object. Legend has it that King Charles II of England did this with his courtiers. V. S. Ramachandran reported, “He used to make their heads disappear. One story is that he used to do it to people he had sentenced to die, to see what they would look like without their heads.”

Teach

Flip It

Students can get some additional help understanding the role of rods and cones by watching the Flip It Video: Rods and Cones in the Retina.

Because cones detect color and rods do not, students might not realize that their peripheral vision is very poor at judging color. Have a student sit in a chair and fixate on a point straight ahead. Stand to the side of the student, at a 180° angle, with a colored marker or piece of colored paper against a neutral background. Move in a semicircle toward the student’s center of vision, asking periodically if the student can tell what color the marker is. Repeated guessing will prove incorrect until the marker is close to the center of the field of vision where the cones reside.

Table 18.1  Receptors in the Human Eye: Rod-Shaped Rods and Cone-Shaped Cones

<table>
<thead>
<tr>
<th></th>
<th>Cones</th>
<th>Rods</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number</td>
<td>6 million</td>
<td>120 million</td>
</tr>
<tr>
<td>Location in retina</td>
<td>Center</td>
<td>Periphery</td>
</tr>
<tr>
<td>Sensitivity in dim light</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Color sensitivity</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Detail sensitivity</td>
<td>High</td>
<td>Low</td>
</tr>
</tbody>
</table>

When you enter a darkened theater or turn off the light at night, your eyes adapt. Your pupils dilate to allow more light to reach your retina, but it typically takes 20 minutes or more before your eyes fully adapt. You can demonstrate dark adaptation by closing or covering one eye for up to 20 minutes. Then make the light in the room not quite bright enough to read this book with your open eye. Now open the dark-adapted eye and read (easily). This period of dark adaptation matches the average natural twilight transition between the Sun’s setting and darkness. How wonderfully made we are.

Visual Information Processing

How do the eye and the brain process visual information?

Visual information percolates through progressively more abstract levels on its path through the thalamus and on to the visual cortex. At the entry level, information processing begins in the retina’s neural layers, which are actually brain tissue that has migrated to the eye during early fetal development. These layers don’t just pass along electrical impulses; they also help to encode and analyze sensory information. The third neural layer in a frog’s eye, for example, contains the “bug detector” cells that fire only in response to moving fly-like stimuli.
After processing by your retina's nearly 130 million receptor rods and cones, information travels to your bipolar cells, then to your million or so ganglion cells, and through their axons making up the optic nerve to your brain. Any given retinal area relays its information to a corresponding location in the visual cortex, in the occipital lobe at the back of your brain (FIGURE 18.6).

The same sensitivity that enables retinal cells to fire messages can lead them to misfire, as you can demonstrate for yourself. Turn your eyes to the left, close them, and then gently rub the right side of your right eyelid with your fingertip. Note the patch of light to the left, moving as your finger moves. Why do you see light? Why at the left?

Your retinal cells are so responsive that even pressure triggers them. But your brain interprets their firing as light. Moreover, it interprets the light as coming from the left—the normal direction of light that activates the right side of the retina.

Feature Detection

David Hubel and Torsten Wiesel (1979) received a Nobel Prize for their work on feature detectors. These specialized neurons in the occipital lobe's visual cortex receive information from individual ganglion cells in the retina. Feature detector cells derive their name from their ability to respond to a scene's specific features—to particular edges, lines, angles, and movements. These cells pass this information to other cortical areas, where teams of cells (supercell clusters) respond to more complex patterns. As we noted in Module 12, one temporal lobe area by your right ear (FIGURE 18.7 on the next page) enables you to perceive faces and, thanks to a specialized neural network, to recognize them from varied viewpoints (Connor, 2010). If this region were damaged, you might recognize other forms and objects, but, like Heather Sellers, not familiar faces. When researchers temporarily disrupt the brain's face-processing areas with magnetic pulses, people are unable to recognize faces.

They will, however, be able to recognize houses, because the brain's face-perception occurs separately from its object-perception (McKone et al., 2007; Pitcher et al., 2007). Thus, functional MRI (fMRI) scans show different brain areas activating when people...
TEACH

Concept Connections

Remind students that the human brain is uniquely capable of parallel processing, as discussed in Unit III. Computers process serially, only able to do one process at a time. Humans can process multiple types of stimuli from the environment, making us more efficient in understanding the world than computers. In fact, our visual system is so adept at parallel processing and, thus, so complicated, that no computer has been invented that can re-create it.

Parallel Processing

Our brain achieves these and other remarkable feats by means of parallel processing: doing many things at once. To analyze a visual scene, the brain divides it into subdimensions—motion, form, depth, color—and works on each aspect simultaneously (Livingstone & Hubel, 1988). We then construct our perceptions by integrating the separate but parallel work of these different visual teams (FIGURE 18.9).
To recognize a face, your brain integrates information projected by your retinas to several visual cortex areas, compares it with stored information, and enables you to recognize the face: "Grandmother!" Scientists are debating whether this stored information is contained in a single cell or distributed over a network. Some supercells—"grandmother cells"—do appear to respond very selectively to 1 or 2 faces in 100 (Bowers, 2009). The whole facial recognition process requires tremendous brain power—30 percent of the cortex (10 times the brain area devoted to hearing).

Destroy or disable a neural workstation for a visual subtask, and something peculiar results, as happened to "Mrs. M." (Hoffman, 1998). Since a stroke damaged areas near the rear of both sides of her brain, she has been unable to perceive movement. People in a room seem "suddenly here or there but I have not seen them moving." Pouring tea into a cup is a challenge because the fluid appears frozen—she cannot perceive it rising in the cup.

After stroke or surgery damage to the brain’s visual cortex, others have experienced blindsight (a phenomenon we met in Module 13). Shown a series of sticks, they report seeing nothing. Yet when asked whether the sticks are vertical or horizontal, their visual intuition typically offers the correct response. When told, "You got them all right," they are astounded. There is, it seems, a second "mind"—a parallel processing system—operating unseen. These separate visual systems for perception and action illustrate dual processing—the two-track mind.

Think about the wonders of visual processing. As you look at that tiger in the zoo, information enters your eyes, is transduced, and is sent to your brain as millions of neural impulses. As your brain buzzes with activity, various areas focus on different aspects of the tiger’s image. Finally, in some as yet mysterious way, these separate teams pool their work to produce a meaningful image, which you compare with previously stored images and recognize: a crouching tiger (FIGURE 18.10).

**Parallel processing**

- Studies of patients with brain damage suggest that the brain delegates the work of processing motion, form, depth, and color to different areas. After taking a scene apart, the brain integrates these subdimensions into the perceived image. How does the brain do this? The answer to this question is the Holy Grail of vision research.

**Figure 18.9**

Parallel processing: Studies of patients with brain damage suggest that the brain delegates the work of processing motion, form, depth, and color to different areas. After taking a scene apart, the brain integrates these subdimensions into the perceived image. How does the brain do this? The answer to this question is the Holy Grail of vision research.

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**ENGAGE**

**Enrichment**

Those with blindsight, argues Anthony Marcel of Cambridge University, have superb vision but they don’t know they can see. Employing a high-speed camera, Marcel tracked the arms, hands, and fingers of individuals with blindsight as they reached for objects they could not consciously see. The films indicate that their reach was quite precise. This suggests that their vision remains intact; only the neural areas that bring vision into awareness are impaired.

**Online Activities**

Blindsight occurs when people experience damage to the visual cortex of the brain. Their eyes are fully functioning, but they report they cannot see even when they demonstrate that they can. For an interesting demonstration of blindsight, as well as additional description of the phenomenon, have students visit the Serendip Brain and Behavior site at http://serendip.brynmawr.edu/bb/blindsight.html.
Think, too, about what is happening as you read this page. The printed squiggles are transmitted by reflected light rays onto your retina, which triggers a process that sends nerve impulses to several areas of your brain, which integrates the information and decodes meaning, thus completing the transfer of information across time and space from my mind to your mind. That all of this happens instantly, effortlessly, and continuously is indeed awesome. As Roger Sperry (1985) observed, the “insights of science give added, not lessened, reasons for awe, respect, and reverence.”

**Color Vision**

What theories help us understand color vision?

We talk as though objects possess color: “A tomato is red.” Perhaps you have pondered the old question, “If a tree falls in the forest and no one hears it, does it make a sound?” We can ask the same question: If no one sees the tomato, is it red?

The answer is no. First, the tomato is everything but red, because it reflects (refracts) the long wavelengths of red. Second, the tomato’s color is our mental construction. As Isaac Newton (1704) noted, “The light rays are not colored.” Color, like all aspects of vision, resides not in the object but in the theater of our brain, as evidenced by our dreaming in color.

One of vision’s most basic and intriguing mysteries is how we see the world in color. How, from the light energy striking the retina, does the brain manufacture our experience of color—and of such a multitude of colors? Our difference threshold for colors is so low that we can discriminate more than 1 million different color variations (Neitz et al., 2001). At least most of us can. For about 1 person in 50, vision is color deficient—and that person is usually male, because the defect is genetically sex-linked.

Why is some people’s vision deficient? To answer that question, we need to understand how normal color vision works. Modern detective work on this mystery began in the nineteenth century, when Hermann von Helmholtz built on the insights of an English physicist, Thomas Young. Knowing that any color can be created by combining the light waves of three primary colors—red, green, and blue—Young and von Helmholtz inferred that the eye must have three corresponding types of color receptors. Years later, researchers measured the response of various cones to different color stimuli and confirmed the Young-Helmholtz trichromatic (three-color) theory, which implies that the receptors do their color magic in teams of three. Indeed, the retina has three types of color receptors, each especially sensitive to one of three colors. And those colors are, in fact, red, green, and blue. When we stimulate combinations of these cones, we see other colors. For example, there are no receptors especially sensitive to yellow. We see yellow when mixing red and green light, which stimulates both red-sensitive and green-sensitive cones.

Most people with color-deficient vision are not actually “colorblind.” They simply lack functioning red- or green-sensitive cones, or sometimes both. Their vision—perhaps unknown to them, because their lifelong vision seems normal—is monochromatic (one-color) or dichromatic (two-color) instead of trichromatic; making it impossible to distinguish the red and green in Figure 18.11 (Boynton, 1979). Dogs, too, lack receptors for the wavelengths of red, giving them only limited, dichromatic color vision (Neitz et al., 1989).

**Online Activities**

Have students experience color blindness by accessing the following websites:

- [www.neitzvision.com/content/colorblindworld.html](http://www.neitzvision.com/content/colorblindworld.html)
- [www.colourblindawareness.org/colour-blindness/colour-blindness-experience-it/](http://www.colourblindawareness.org/colour-blindness/colour-blindness-experience-it/)

**Interdisciplinary Connections**

Team teach a lesson in subtractive and additive color mixing with your school’s art teacher. Encourage students to combine colors in different levels to create some of the 7 million different hues the human eye can see.
But how is it that people blind to red and green can often still see yellow? And why does yellow appear to be a pure color and not a mixture of red and green, the way purple is of red and blue? As Ewald Hering soon noted, trichromatic theory leaves some parts of the color vision mystery unsolved.

Hering, a physiologist, found a clue in afterimages. Stare at a green square for a while and then look at a white sheet of paper, and you will see red, green’s opponent color. Stare at a yellow square and its opponent color, blue, will appear on the white paper. (To experience this, try the flag demonstration in Figure 18.12.) Hering surmised that there must be two additional color processes, one responsible for red-versus-green perception, and one for blue-versus-yellow.

Indeed, a century later, researchers also confirmed Hering’s opponent-process theory. Three sets of opponent retinal processes—red-green, yellow-blue, and white-black—enable color vision. In the retina and in the thalamus (where impulses from the retina are relayed en route to the visual cortex), some neurons are turned “on” by red but turned “off” by green. Others are turned on by green but off by red (DeValois & DeValois, 1975). Like red and green marbles sent down a narrow tube, “red” and “green” messages cannot both travel at once. So we do not experience a reddish green. (Red and green are thus opponents.) But red and blue travel in separate channels, so we can see a reddish-blue magenta.

So how do we explain afterimages, such as in the flag demonstration? By staring at green, we tire our green response. When we then stare at white (which contains all colors, including red), only the red part of the green-red pairing will fire normally.

The present solution to the mystery of color vision is therefore roughly this: Color processing occurs in two stages. The retina’s red, green, and blue cones respond in varying degrees to different color stimuli, as the Young-Helmholtz trichromatic theory suggested. Their signals are then processed by the nervous system’s opponent-process cells, as Hering’s theory proposed.

**Close & Assess**

**Exit Assessment**

Provide students with a diagram of the eye (such as Figure 18.3) and have them label the diagram with the correct parts of the eye. Also have them explain the function of each part, making sure students know how light is received by the eye and transferred to the brain for processing.
Module 18 Review

1. What is the energy that we see as visible light, and how does the eye transform light energy into neural messages?

- The hue we perceive in light depends on its wavelength, and its brightness depends on its intensity.
- After entering the eye and being focused by the lens, light energy particles (from a thin slice of the broad spectrum of electromagnetic energy) strike the eye’s inner surface, the retina. The retina’s light-sensitive rods and color-sensitive cones convert the light energy into neural impulses.

2. How do the eye and the brain process visual information?

- After processing by bipolar and ganglion cells in the eyes’ retina, neural impulses travel through the optic nerve to the thalamus, and on to the visual cortex. In the visual cortex, feature detectors respond to specific features of the visual stimulus. Superell clusters in other critical brain areas respond to more complex patterns.
- Through parallel processing, the brain handles many aspects of vision (color, movement, form, and depth) simultaneously. Other neural teams integrate the results, comparing them with stored information and enabling perceptions.

Multiple-Choice Questions

1. Light’s _______ is the distance from one wave peak to the next. This dimension determines the ______ we experience.
   a. hue; wavelength
   b. wavelength; hue
   c. hue; intensity
   d. wavelength; intensity
   e. intensity; wavelength

2. What do we call the specialized neurons in the occipital lobe’s visual cortex that respond to particular edges, lines, angles, and movements?
   a. Rods
   b. Cones
   c. Foveas
   d. Feature detectors
   e. Ganglion cells

3. Which of the following explains reversed-color afterimages?
   a. Young-Helmholtz trichromatic theory
   b. The blind spot
   c. Hering’s opponent-process theory
   d. Feature detectors
   e. Parallel processing

4. Your best friend decides to paint her room an extremely bright electric blue. Which of the following best fits the physical properties of the color’s light waves?
   a. No wavelength; large amplitude
   b. Short wavelength, large amplitude
   c. Short wavelength, small amplitude
   d. Long wavelength, large amplitude
   e. No wavelength; small amplitude

What theories help us understand color vision?

- The Young-Helmholtz trichromatic (three-color) theory proposed that the retina contains three types of color receptors. Contemporary research has found three types of cones, each most sensitive to the wavelengths of one of the three primary colors of light (red, green, or blue).
- Hering’s opponent-process theory proposed three additional color processes (red-versus-green, blue-versus-yellow, black-versus-white). Contemporary research has confirmed that, en route to the brain, neurons in the retina and the thalamus code the color-related information from the cones into pairs of opponent colors.
- These two theories, and the research supporting them, show that color processing occurs in two stages.

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- These two theories, and the research supporting them, show that color processing occurs in two stages.
Practice FRQs

1. As light reflected off an object reaches your eye, it passes through several structures before it reaches the retina. Describe three of these structures, including the function of each.

   Answer
   1 point: The cornea is at the front of the eye. It bends and focuses the light waves.
   1 point: The pupil is the opening through which light enters the eyeball. It is surrounded by the iris, which can expand or contract to allow more or less light to pass through the pupil.
   1 point: The lens is the transparent structure behind the pupil that changes shape to help focus images on the retina.

2. Explain two theories of color vision in humans. How does one of them explain color deficiency? (3 points)

   1 point: The Young–Helmholtz trichromatic theory states that we have 3 color receptors within the eye: red, green, and blue.
   1 point: The opponent process theory says that retinal processes only occur in 3 sets of opponents: red/green, yellow/blue, and white/black.
   1 point: You can explain color deficiency as a dysfunction of red- or green-sensitive cones (trichromatic theory) or as a problem with the red–green opponent processes (opponent process theory).
Module 19

Visual Organization and Interpretation

Module Learning Objectives

- Describe Gestalt psychologists’ understanding of perceptual organization, and explain how figure-ground and grouping principles contribute to our perceptions.
- Explain how we use binocular and monocular cues to perceive the world in three dimensions and perceive motion.
- Explain how perceptual constancies help us organize our sensations into meaningful perceptions.
- Describe what research on restored vision, sensory restriction, and perceptual adaptation reveals about the effects of experience on perception.

Visual Organization

19-1 How did the Gestalt psychologists understand perceptual organization, and how do figure-ground and grouping principles contribute to our perceptions?

It’s one thing to understand how we see shapes and colors. But how do we organize and interpret those sights (or sounds or tastes or smells) so that they become meaningful perceptions—a rose in bloom, a familiar face, a sunset?

Early in the twentieth century, a group of German psychologists noticed that when given a cluster of sensations, people tend to organize them into a gestalt, a German word meaning a “form” or a “whole.” For example, look at FIGURE 19.1. Note that the individual elements of this figure, called a Necker cube, are really nothing but eight blue circles, each containing three converging white lines. When we view these elements all together, however, we see a cube that sometimes reverses direction. This phenomenon nicely illustrates a favorite saying of Gestalt psychologists: In perception, the whole may exceed the sum of its parts. If we combine sodium (a corrosive metal) with chlorine (a poisonous gas), something very different emerges—table salt. Likewise, a unique perceived form emerges from a stimulus’ components (Rock & Palmer, 1990).

AP® Exam Tip

The Necker cube is an excellent vehicle for understanding the distinction between sensation and perception. The only visual stimuli are the blue wedges. The circles, lines, and cube are all the products of perception—they are in your mind and not on the page.
Form Perception
Imagine designing a video-computer system that, like your eye-brain system, can recognize faces at a glance. What abilities would it need?

FIGURE AND GROUND
To start with, the video-computer system would need to separate faces from their backgrounds. Likewise, in our eye-brain system, our first perceptual task is to perceive any object (the figure) as distinct from its surroundings (the ground). Among the voices you hear at a party, the one you attend to becomes the figure; all others are part of the ground. As you read, the words are the figure; the white paper is the ground. Sometimes the same stimulus can trigger more than one perception. In FIGURE 19.2, the figure-ground relationship continually reverses—but always we organize the stimulus into a figure seen against a ground.

GROUPING
Having discriminated figure from ground, we (and our video-computer system) must also organize the figure into a meaningful form. Some basic features of a scene—such as color, movement, and light-dark contrast—we process instantly and automatically (Treisman, 1987). Our minds bring order and form to stimuli by following certain rules for grouping. These rules, identified by the Gestalt psychologists and applied even by infants, illustrate how the perceived whole differs from the sum of its parts (Quinn et al., 2002; Rock & Palmer, 1990). Three examples:

PROXIMITY: We group nearby figures together. We see not six separate lines, but three sets of two lines.

CONTINUITY: We perceive smooth, continuous patterns rather than discontinuous ones. This pattern could be a series of alternating semicircles, but we perceive it as two continuous lines—one wavy, one straight.

CLOSURE: We fill in gaps to create a complete, whole object. Thus we assume that the circles on the right are complete but partially blocked by the (illusory) triangle. Add nothing more than little line segments to close off the circles and your brain stops constructing a triangle. Such principles usually help us construct reality.

Similarity: Items that look the same are usually grouped together. Have students imagine their reactions when someone they do not know well wears the same outfit or shirt as they do. Typically, they are uncomfortable with this because we do not like being grouped with people we do not know well.

TEACH
Teaching Tip
Use the following examples of 2 of the gestalt grouping principles to help students remember them:

- **Proximity:** We perceive items that are close to each other as being together. Have students imagine their reactions when someone they do not know well walks in step with them down the hall. Typically, people feel discomfort when this happens because of their proximity to the other person. We do not like to be grouped together with people we do not know well.

- **Similarity:** Items that look the same are usually grouped together. Have students imagine their reactions when someone they do not know well wears the same outfit or shirt as they do. Typically, they are uncomfortable with this because we do not like being grouped with people we do not know well.

Active Learning
Students can discover auditory figure–ground illusions by simply repeating aloud a word such as say. It will shift abruptly to ace and back again to say.

Common Pitfalls
Students typically find gestalt grouping principles to be very mundane and obvious. Remind students that the Gestalt psychologists were the first to study systematically how people perceive whole objects. Before their work, people took these grouping principles for granted.
TEACH
Concept Connections
Refer students to Unit IX for a thorough discussion of infant development. The visual cliff study, a classic in the field, helped demonstrate how infants perceive depth and ways to measure infant perceptions without relying on language.

ENGAGE
TRM Enrichment
We are able to perceive depth because we have 2 eyes in the front of our heads. Animals with eyes on the sides of their heads need that type of vision to scan for danger around them. Peripheral vision is much better at detecting motion, so stronger peripheral vision through eyes on the sides of the head gives an evolutionary advantage to animals that are typically hunted. Predators do not need to be on the look out for danger—they are the danger! They need to determine distances between them and their prey, which requires the depth perception that binocular vision provides. Use Student Activity: Binocular Vision Versus Monocular Vision from the TRM to demonstrate the value of binocular cues.

Depth Perception
19-2 How do we use binocular and monocular cues to perceive the world in three dimensions and perceive motion?

From the two-dimensional images falling on our retinas, we somehow organize three-dimensional perceptions. Depth perception enables us to estimate an object’s distance from us. At a glance, we can estimate the distance of an oncoming car or the height of a house. Depth perception is partly innate, as Eleanor Gibson and Richard Walk (1960) discovered using a model of a cliff with a drop-off area (which was covered by sturdy glass). Gibson’s inspiration for these visual cliff experiments occurred while she was picnicking on the rim of the Grand Canyon. She wondered: Would a toddler peering over the rim perceive the dangerous drop-off and draw back?

Back in their Cornell University laboratory, Gibson and Walk placed 6- to 14-month-old infants on the edge of a safe canyon and had the infants’ mothers coax them to crawl out onto the glass (Figure 19.3). Most infants refused to do so, indicating that they could perceive depth.

Had they learned to perceive depth? Learning seems to be part of the answer because crawling, no matter when it begins, seems to increase infants’ wariness of heights (Campos et al., 1992). Yet, the researchers observed, mobile newborn animals come prepared to perceive depth. Even those with virtually no visual experience—including young kittens, a day-old goose, and newly hatched chickens—will not venture across the visual cliff. Thus, it seems that biology predisposes us to be wary of heights and experience amplifies that fear.

How do we perceive depth? How do we transform two differing two-dimensional (2-D) retinal images into a single three-dimensional (3-D) perception? Our brain constructs these perceptions using information supplied by one or both eyes.

BINOCULAR CUES
Try this: With both eyes open, hold two pens or pencils in front of you and touch their tips together. Now do so with one eye closed. With one eye, the task becomes noticeably more difficult, demonstrating the importance of binocular cues in judging the distance of nearby objects. Two eyes are better than one.

Because your eyes are about 2½ inches apart, your retinas receive slightly different images from the outside world, depending on the use of both eyes. Binocular cues are, such as retinal disparity, that depend on the use of two eyes.

Figure 19.3 Visual cliff. Eleanor Gibson and Richard Walk devised a miniature cliff with a glass-covered drop-off to determine whether crawling infants can perceive depth. Even when their arms are reeled at the bottom of the cliff, infants are reluctant to venture onto the glass (Gibson & Walk, 1960).

depth perception the ability to see objects in three dimensions although the images that strike the retina are two-dimensional, allows us to judge distance.

visual cliff a laboratory device for testing depth perception in infants and young animals.

binocular cues depth cues, such as retinal disparity, that depend on the use of two eyes.

retinal disparity a binocular cue for perceiving depth. By comparing images from the retinas in the two eyes, the brain computes distance—the greater the disparity (difference) between the two images, the closer the object.

Online Activities
Some people cannot see depth well because of different conditions that hinder the eyes’ ability to see in stereo. Check out www.vision3d.com to find the answers to the following questions:

- What is amblyopia (lazy eye)? What are some treatments for this condition?
- What is strabismus (deflected eye, crossed eyes, or wall eyes)? What are some treatments for this condition?
- How are vision problems related to learning disabilities and dyslexia?
The resulting 3-D effect, as 3-D movie fans know, mimics or exaggerates normal retinal disparity. Similarly, twin cameras in airplanes can take photos of terrain for integration into 3-D maps.

**MONOCULAR CUES**

How do we judge whether a person is 10 or 100 meters away? Retinal disparity won’t help us here, because there won’t be much difference between the images cast on our right and left retinas. But at such distances, we depend on monocular cues (depth cues available to each eye separately). See Figure 19.5 on the next page for some examples.

**Motion Perception**

Imagine that you could perceive the world as having color, form, and depth but that you could not see motion. Not only would you be unable to bike or drive, you would have trouble writing, eating, and walking.

Normally your brain computes motion based partly on its assumption that shrinking objects are retreating (not getting smaller) and enlarging objects are approaching. But you are imperfect at motion perception. Large objects, such as trains, appear to move more slowly than smaller objects, such as cars, moving at the same speed. (Perhaps at an airport you’ve noticed that jumbo jets seem to land more slowly than little jets.)

To catch a fly ball, softball or cricket players (unlike drivers) want to achieve a collision—with the ball that’s flying their way. To accomplish that, they follow an unconscious rule—one they can’t explain but know intuitively. Run to keep the ball at a constantly increasing angle of gaze (McBeath et al., 1995). A dog catching a Frisbee does the same (Shaffer et al., 2001).

The brain also perceives continuous movement in a rapid series of slightly varying images (a phenomenon called stroboscopic movement). As film animation artists know well, you can create this illusion by flashing 24 still pictures a second. The motion we then see in popular action adventures is not in the film, which merely presents a superfast slide show. We construct that motion in our heads, just as we construct movement in blinking marquises and holiday lights. When two adjacent stationary lights blink on and off in quick succession, we perceive a single light moving back and forth between them. Lighted signs exploit this phi phenomenon with a succession of lights that creates the impression of, say, a moving arrow.

*From there to here, from here to there, funny things are everywhere.* —Dr. Seuss, *Two Fish, Red Fish, Blue Fish, 1960.*

*Sometimes I wonder: Why is that Frisbee getting bigger? And then it hits me.* —Anonymous

**ENGAGE**

**Active Learning**

Have students close 1 eye, point their 2 forefingers toward each other, and then bring them together quickly. They are likely to miss. An even more difficult test is to have them hold a pencil in each hand and bring the points together. It is important, of course, that their hands not be at arm’s length. If they repeat either test, they ought to drop their arms out of view before they try again. This will eliminate the perception of any depth cues from the position of the hands and arms.

**ENGAGE**

**Enrichment**

Although we can see depth with only 1 eye, it is much more difficult to perceive depth with 1 eye closed than with both eyes open. Animals with eyes on the sides of their heads (birds, rabbits, etc.) tend to compensate for their lack of depth perception by moving their heads around a lot to as they try to look around objects. This type of movement, which creates depth, is called monocular parallax.

**ENGAGE**

**Active Learning**

Try to round up some Viewmasters to demonstrate retinal disparity in class. Students can view the images with 1 eye closed and both eyes open to see how the same image is projected in 2 slightly different places to capitalize on our perception of depth. Use Student Activity: Autostereograms from the TRM to demonstrate depth perception using a Magic Eye™-like activity.

**ENGAGE**

**Active Learning**

Have students roll a sheet of paper into a tube and raise it to their right eye like a telescope. Tell them to look through it, focusing on a blank wall in front of them. Next, have them hold their left hand open beside the tube and continue to focus ahead. The images received by the 2 eyes will fuse, and the hole in the tube will appear to be in the student’s hand. They may need to slide the hand alongside the tube until they find the precise spot where the hole appears to go through the very center of the palm.


**ENGAGE**

**Online Activities**

In a computer lab or as a homework assignment, have students try out some of the 3D vision games found in the Optometrists Network at www.vision3d.com.

- Eye Hop Game: www.vision3d.com/ehop.html
- Framing Game: www.vision3d.com/frame.html
- Reversible figures: www.vision3d.com/optical/puzzles.html

*Figure 19.4 The floating finger sausage.* Hold your two index fingers about 5 inches in front of your eyes, with their tips half an inch apart. Now look beyond them and note the weird result. Move your fingers out farther and the retinal disparity—and the finger sausage—will shrink.
Common Pitfalls
Students may feel that the monocular depth cues are more common sense than psychology. Emphasize that without these cues, many forms of entertainment—from art to television to movies—would lack the visual richness and beauty they possess. Monocular depth cues help make the world a more visually interesting place!

Teaching Tip
Divide students into small groups and have them compile a portfolio of examples of monocular depth cues. Have them bring in their own magazines (or collect back issues from your library) to look for examples of each type of monocular cue, collecting them in a scrapbook or poster and identifying the one that each picture exemplifies.

Teaching Tip
Many of these monocular depth cues rely on previous knowledge in order to work. If we don’t already know how large an object is, then the relative size cue becomes meaningless. Here is where top-down processing is most useful in helping us accurately understand the world. Have students explain how top-down processing is useful.

Teaching Tip
Students can get some additional help understanding monocular cues by watching the Flip It Video: Monocular Cues.

Perceptual Constancy
How do perceptual constancies help us organize our sensations into meaningful perceptions?
So far, we have noted that our video-computer system must perceive objects as we do—as having a distinct form, location, and perhaps motion. Its next task is to recognize objects without being deceived by changes in their color, brightness, shape, or size—a top-down process called perceptual constancy. Regardless of the viewing angle, distance, and illumination, we can identify people and things in less time than it takes to draw a breath, a feat that would be a monumental challenge for even advanced computers and that has intrigued researchers for decades.

TEACH
Active Learning
Boston’s Museum of Science offers a wonderful online lesson in which students can create a realistic and natural picture using linear perspective. The Leonardo’s Window lesson asks students to tape some acetate onto a window and trace the lines found in the natural world outside to create a painting. For more instructions, see http://legacy.mos.org/sln/Leonardo/UsingLeosWindow.html.

TEACH
Teaching Tip
Another monocular cue students should know is texture gradient. This is the tendency for textured surfaces to appear to become smaller and finer as distance from the viewer increases. For example, a hiker in a field of flowers will see the closest flowers clearly, but the details of the flowers become less apparent and seem smaller the farther into the distance he looks.
COLOR AND BRIGHTNESS CONSTANCIES

Color does not reside in an object. Our experience of color depends on the object’s context. If you view an isolated tomato through a paper tube, its color would seem to change as the light— and thus the wavelengths reflected from its surface— changed. But if you viewed that tomato as one item in a bowl of fresh fruit and vegetables, its color would remain roughly constant as the lighting shifts. This perception of consistent color is known as color constancy.

Though we take color constancy for granted, this ability is truly remarkable. A blue poker chip under indoor lighting reflects wavelengths that match those reflected by a sunlit gold chip (Jameson, 1985). Yet bring a bluebird indoors and it won’t look like a goldfinch. The color is not in the bird’s feathers but in the brain’s computations of the light reflected by an object relative to the objects surrounding it. (But only if we grew up with normal light, it seems. Monkeys raised under a restricted range of wavelengths later have great difficulty recognizing the same color when illumination varies [Sugita, 2004].) Figure 19.6 dramatically illustrates the ability of a blue object to appear very different in three different contexts. Yet we have no trouble seeing these disks as blue.

Similarly, brightness constancy (also called lightness constancy) depends on context. We perceive an object as having a constant brightness even while its illumination varies. This perception of constancy depends on relative luminance—the amount of light an object reflects relative to its surroundings (Figure 19.7 on the next page). White paper reflects 90 percent of the light falling on it; black paper, only 10 percent. Although a black paper viewed in sunlight may reflect 100 times more light than does a white paper viewed indoors, it will still look black (McBurney & Collings, 1984). But if you view sunlit black paper through a narrow tube so nothing else is visible, it may look gray, because in bright sunshine it reflects a fair amount of light. View it without the tube and it is again black, because it reflects much less light than the objects around it.

This principle—that we perceive objects not in isolation but in their environmental context—matters to artists, interior decorators, and clothing designers. Our perception of the color and brightness of a wall or of a streak of paint on a canvas is determined not just by the paint in the can but by the surrounding colors. The take-home lesson: Comparisons govern our perceptions.
TEACH

Teaching Tip
Have students imagine how disturbing the world would be if we suddenly lost our ability to perceive constancy. What if objects appeared to change shape when they moved? What if color became different in different levels of light? "My monster little brother" would take on a whole new meaning if he grew and changed shapes and colors right before your eyes!

ENGAGE

Active Learning
The importance of perceptual constancy is demonstrated in the following passage:

I cdnuolt blveiee taht I cluoed aulaclty uesdnatnrd waht I was rdanieg. Takhns to the phaonmneal pweor of the hmuan mnid, aoccdrnig to rscheearch at Cmabrigde Uinervtisy, it deosn't mttaer in waht oredr the ltteers in a wrod are, the olny iprmoatnt tihng is taht the frist and lsat ltteer be in the rghit pclae. The rset can be a taotl mses and you can stll raed it wouthit a porbelm. Tihs is bcuseae the huamn mnid deos not raed ervey ltteer by istlef, but the wrod as a wlohe. Amzanig, huh? Yaeh and I awlyas tghuhot slpeling was ipmorantt! if you can raed tihs, psas it on!!

While this popular Internet message was not really based on a study by Cambridge University, and its scientific validity is in serious doubt, the fact that people can still decipher this paragraph is testimony to the power of the brain to make sense out of nonsense. Have students discuss ways to test the claims of this passage scientifically.

SHAPE AND SIZE CONSTANCIES

Sometimes an object whose actual shape cannot change seems to change shape with the angle of our view (FIGURE 19.8). More often, thanks to shape constancy, we perceive the form of familiar objects, such as the door in FIGURE 19.9, as constant even while our retinas receive changing images of them. Our brain manages this feat thanks to visual cortex neurons that rapidly learn to associate different views of an object (Li & DiCarlo, 2008).

Thanks to size constancy, we perceive objects as having a constant size, even while our distance from them varies. We assume a car is large enough to carry people, even when we see its tiny image from two blocks away. This assumption also illustrates the close connection between perceived distance and perceived size. Perceiving an object’s distance gives us cues to its size. Likewise, knowing its general size—that the object is a car—provides us with cues to its distance.

Figure 19.7
Relative luminance  Squares A and B are identical in color, believe it or not. If you don’t believe me, photocopy the illustration, cut out the squares, and compare. But we perceive A as lighter, thanks to its surrounding context.

Figure 19.8
Perceiving shape  Do the tops of these tables have different dimensions? They appear to. But—believe it or not—they are identical. (Measure and see.) With both tables, we adjust our perceptions relative to our viewing angle.

Figure 19.9
Shape constancy  A door casts an increasingly trapezoidal image on our retinas as it opens, yet we still perceive it as rectangular.
Even in size-distance judgments, however, we consider an object’s context. The dogs in Module 17’s Figure 17.3 cast identical images on our retinas. Using linear perspective as a cue (see Figure 19.5), our brain assumes that the pursuing dog is farther away. We therefore perceive it as larger. It isn’t.

This interplay between perceived size and perceived distance helps explain several well-known illusions, including the Moon illusion: The Moon looks up to 50 percent larger when near the horizon than when high in the sky. Can you imagine why? For at least 22 centuries, scholars have debated this question (Hershenson, 1989). One reason is that cues to objects’ distances make the horizon Moon—like the distant dog in Figure 17.3—appear farther away. If it’s farther away, our brain assumes, it must be larger than the Moon high in the night sky (Kaufman & Kaufman, 2000). Take away the distance cue, by looking at the horizon Moon (or each dog) through a paper tube, and the object will immediately shrink.

Size-distance relationships also explain why in FIGURE 19.10 the two same-age girls seem so different in size. As the diagram reveals, the girls are actually about the same size, but the room is distorted. Viewed with one eye through a peephole, the room’s trapezoidal walls produce the same images you would see in a normal rectangular room viewed with both eyes. Presented with the camera’s one-eyed view, your brain makes the reasonable assumption that the room is normal and each girl is therefore the same distance from you. Given the different sizes of the girls’ images on your retinas, your brain ends up calculating that the girls must be very different in size.

Perceptual illusions reinforce a fundamental lesson: Perception is not merely a projection of the world onto our brain. Rather, our sensations are disassembled into information bits that our brain, using both bottom-up and top-down processing, then reassembles into its own functional model of the external world. During this reassembly process, our assumptions—such as the usual relationship between distance and size—can lead us astray. Our brain constructs our perceptions.

Form perception, depth perception, motion perception, and perceptual constancies illuminate how we organize our visual experiences. Perceptual organization applies to our other senses, too. It explains why we perceive a clock’s steady tick not as a tick-tick-tick-tick but as grouped sounds, say, TICK-tick, TICK-tick. Listening to an unfamiliar language, we have trouble hearing where one word stops and the next one begins. Listening to our own language, we automatically hear distinct words. This, too, reflects perceptual organization. But it is more, for we even organize a string of letters—THEDOGATEMEAT—into words that make an intelligible phrase, more likely “The dog ate meat” than “The do gate me at” (McBurney & Collings, 1984). This process involves not only the organization we’ve been discussing, but also interpretation—discerning meaning in what we perceive.
Visual Interpretation

Philosophers have debated whether our perceptual abilities should be credited to our nature or our nurture. To what extent do we learn to perceive? German philosopher Immanuel Kant (1724–1804) maintained that knowledge comes from our innate ways of organizing sensory experiences. Indeed, we come equipped to process sensory information. But British philosopher John Locke (1632–1704) argued that through our experiences we also learn to perceive the world. Indeed, we learn to link an object’s distance with its size. So, just how important is experience? How radically does it shape our perceptual interpretations?

Experience and Visual Perception

What does research on restored vision, sensory restriction, and perceptual adaptation reveal about the effects of experience on perception?

RESTORED VISION AND SENSORY RESTRICTION

Writing to John Locke, William Molyneux wondered whether “a man born blind, and now adult, taught by his touch to distinguish between a cube and a sphere” could, if made to see, visually distinguish the two. Locke’s answer was No, because the man never would have learned to see the difference.

Molyneux’s hypothetical case has since been put to the test with a few dozen adults who, though blind from birth, have gained sight (Gregory, 1978; von Senden, 1932). Most had been born with cataracts—clouded lenses that allowed them to see only diffused light, rather as someone might see a foggy image through a Ping-Pong ball sliced in half. After cataract surgery, the patients could distinguish figure from ground and could sense colors—suggesting that these aspects of perception are innate. But much as Locke supposed, they often could not visually recognize objects that were familiar by touch.

Seeking to gain more control than is provided by clinical cases, researchers have outfitted infant kittens and monkeys with goggles through which they could see only diffuse, unpatterned light. Use of this type of apparatus is called a Ganzfeld procedure. This procedure is often used to create an experience of sensory deprivation. Use Student Activity: The Ganzfeld from the TRM to demonstrate how the elimination of contours effectively eliminates visual perception.

In both humans and animals, similar sensory restrictions later in life do no permanent harm. When researchers cover the eye of an adult animal for several months, its vision will be unaffected after the eye patch is removed. When surgeons remove cataracts that develop during late adulthood, most people are thrilled at the return to normal vision.

The effect of sensory restriction on infant cats, monkeys, and humans suggests there is a critical period for normal sensory and perceptual development. Nurture sculpts what nature has endowed. In less dramatic ways, it continues to do so throughout our lives. Despite concerns about their social costs (more on this in Module 78), action video games sharpen spatial skills such as visual attention, eye-hand coordination and speed, and tracking multiple objects (Spence & Feng, 2010).

Experiments on early sensory deprivation provide a partial answer to the enduring question about experience: Does the effect of early experience last a lifetime? For some aspects of perception, the answer is clearly No. “Use it or lose it.” We retain the imprint of some early sensory experiences far into the future.
PERCEPTUAL ADAPTATION

Given a new pair of glasses, we may feel slightly disoriented, even dizzy. Within a day or two, we adjust. Our perceptual adaptation to changed visual input makes the world seem normal again. But imagine a far more dramatic new pair of glasses—one that shifts the apparent location of objects 40 degrees to the left. When you first put them on and toss a ball to a friend, it sails off to the left. Walking forward to shake hands with the person, you veer to the left.

Could you adapt to this distorted world? Baby chicks cannot. When fitted with such lenses, they continue to peck where food grains seem to be (Hess, 1956; Rossi, 1968). But we humans adapt to distorting lenses quickly. Within a few minutes your throws would again be accurate, your stride on target. Remove the lenses and you would experience an aftereffect. At first your throws would err in the opposite direction, sailing off to the right; but again, within minutes you would readapt.

Indeed, given an even more radical pair of glasses—one that literally turns the world upside-down—you could still adapt. Psychologist George Stratton (1896) experienced this when he invented, and for eight days wore, optical headgear that flipped left to right and up to down, making him the first person to experience a right-side-up retinal image while standing upright. The ground was up, the sky was down.

At first, when Stratton wanted to walk, he found himself searching for his feet, which were now “up.” Eating was nearly impossible. He became nauseated and depressed. But he persisted, and by the eighth day he could comfortably reach for an object in the right direction and walk without bumping into things. When Stratton finally removed the headgear, he readapted quickly.

In later experiments, people wearing the optical gear have even been able to ride a motorcycle, ski the Alps, and fly an airplane (Dolezal, 1982; Kohler, 1962). The world around them still seemed above their heads or on the wrong side. But by actively moving about in these topsy-turvy worlds, they adapted to the context and learned to coordinate their movements.

Before You Move On

► ASK YOURSELF
Try drawing a realistic depiction of the scene from your window. Which monocular cues will you use in your drawing?

► TEST YOURSELF
What do we mean when we say that, in perception, “the whole is greater than the sum of its parts”?

Answers to the Test Yourself questions can be found in Appendix E at the end of the book.
How did the Gestalt psychologists understand perceptual organization, and how do figure-ground and grouping principles contribute to our perceptions?

- Gestalt psychologists searched for rules by which the brain organizes fragments of sensory data into gestalts (from the German word for "whole"), or meaningful forms. In pointing out that the whole may exceed the sum of its parts, they noted that we filter sensory information and construct our perceptions.
- To recognize an object, we must first perceive it (see it as a figure) as distinct from its surroundings (the ground). We bring order and form to stimuli by organizing them into meaningful groups, following such rules as proximity, continuity, and closure.

How do we use binocular and monocular cues to perceive the world in three dimensions and perceive motion?

- Depth perception is our ability to see objects in three dimensions and judge distance. The visual cliff and other research demonstrate that many species perceive the world in three dimensions at, or very soon after, birth.
- Binocular cues, such as retinal disparity, are depth cues that rely on information from both eyes.
- Monocular cues (such as relative size, interposition, relative height, relative motion, linear perspective, and light and shadow) let us judge depth using information transmitted by only one eye.
- As objects move, we assume that shrinking objects are retreating and enlarging objects are approaching.
- A quick succession of images on the retina can create an illusion of movement, as in stroboscopic movement or the phi phenomenon.

How do perceptual constancies help us organize our sensations into meaningful perceptions?

- Perceptual constancy enables us to perceive objects as stable despite the changing image they cast on our retinas.
  - Color constancy is our ability to perceive consistent color in objects, even though the lighting and wavelengths shift.
  - Brightness (or lightness) constancy is our ability to perceive an object as having a constant lightness even when its illumination—the light cast upon it—changes.
- Our brain constructs our experience of an object’s color or brightness through comparisons with other surrounding objects.
- Shape constancy is our ability to perceive familiar objects (such as an opening door) as unchanging in shape.
- Size constancy is perceiving objects as unchanging in size despite their changing retinal images.

What does research on restored vision, sensory restriction, and perceptual adaptation reveal about the effects of experience on perception?

- Experience guides our perceptual interpretations. People blind from birth who gained sight after surgery lack the experience to visually recognize shapes, forms, and complete faces.
- Sensory restriction research indicates that there is a critical period for some aspects of sensory and perceptual development. Without early stimulation, the brain’s neural organization does not develop normally.
- People given glasses that shift the world slightly to the left or right, or even upside down, experience perceptual adaptation. They are initially disoriented, but they manage to adapt to their new context.
Multiple-Choice Questions

1. A teacher used distortion goggles, which shifted the wearer's gaze 20 degrees, to demonstrate an altered perception. A student wearing the goggles initially bumped into numerous desks and chairs while walking around, but chose to wear the goggles for a half hour. After 30 minutes, the student was able to smoothly avoid obstacles, illustrating the concept of
   a. perceptual adaptation.
   b. visual interpretation.
   c. sensory restriction.
   d. perceptual constancy.
   e. binocular cues.

2. What do we call the illusion of movement that results from two or more stationary, adjacent lights blinking on and off in quick succession?
   a. Phi phenomenon
   b. Perceptual constancy
   c. Binocular cues
   d. Retinal disparity
   e. Depth perception

3. Bryanna and Charles are in a dancing competition. It is easy for spectators to see them against the dance floor because of
   a. the visual cliff.
   b. the phi phenomenon.
   c. color constancy.
   d. sensory restriction.
   e. figure-ground relationships.

4. The view from Narmeen's left eye is slightly different from the view from her right eye. This is due to which depth cue?
   a. Retinal disparity
   b. Relative size
   c. Linear perspective
   d. Relative motion
   e. Convergence

5. Bringing order and form to stimuli, which illustrates how the whole differs from the sum of its parts, is called
   a. grouping.
   b. monocular cue.
   c. binocular cue.
   d. disparity.
   e. motion.

Practice FRQs

1. Look at the relative size cartoon in Figure 19.5. Describe how the artist who drew this cartoon incorporated relative size, linear perspective, and interposition to create depth.

Answer
Specific explanations may utilize different aspects of the cartoon.
1 point: Relative size: We know the woman is closer to us than the police officer, because she is drawn larger.
1 point: Linear perspective: We can tell that the sidewalk is receding into the distance, because its sides pinch closer together in the distance.
1 point: Interposition: We know the woman is closer to us than the police officer, because our view of her partially blocks our view of him.

2. Explain the meaning of the word gestalt as it applies to perception. Then, apply any two gestalt principles to the perception of food on a plate.

(3 points)

Answers to Multiple-Choice Questions

1. a 3. e 5. a
2. a 4. a

Answer to Practice FRQ 2
1 point: A gestalt is a unified whole. We perceive the world in unified groups or patterns.

1 point: Student must apply 2 gestalt principles to the perception of food on a plate. Examples might include:
- Figure–ground: The food is the figure that stands out against the ground of the plate.
- Similarity: A dozen Tater Tots would be perceived as a group because the tots all look pretty much alike.
- Proximity: Green peas would be perceived as a group because they would be near one another on the plate.
Discussion Starter

Use the Module 20 Fact or Falsehood student activity from the TRM to introduce the concepts from this module.

Active Learning

Have band students bring in their instruments to demonstrate how vibrations work with the different instruments.

- What produces the vibrations in each instrument?
- How does the instrument produce louder and softer sounds?

Module 20

Hearing

Module Learning Objectives

20-1 Describe the characteristics of air pressure waves, and explain the process by which the ear transforms sound energy into neural messages.

20-2 Discuss the theories that help us understand pitch perception.

20-3 Describe how we locate sounds.

What are the characteristics of air pressure waves that we hear as sound, and how does the ear transform sound energy into neural messages?

Like our other senses, our audition, or hearing, is highly adaptive. We hear a wide range of sounds, but the ones we hear best are those sounds with frequencies in a range corresponding to that of the human voice. Those with normal hearing are acutely sensitive to faint sounds, an obvious boon for our ancestors' survival when hunting or being hunted, or for detecting a child's whimper. (If our ears were much more sensitive, we would hear a constant hiss from the movement of air molecules.)

We are also remarkably attuned to variations in sounds. We easily detect differences among thousands of possible human voices. Walking between classes, we immediately recognize the voice of a friend behind us. A fraction of a second after a spoken word stimulates the ear's receptors, millions of neurons have simultaneously coordinated in extracting the essential features, comparing them with past experience, and identifying the stimulus (Freeman, 1991).

But not everyone has this ability. Some years ago, on a visit to my childhood home, I communicated with my then 80-year-old mother by writing on her erasable "magic pad." Four years earlier she had transitioned from hearing loss to complete deafness by giving up her now useless hearing aids.

"Do you hear anything?" I wrote.

"No," she answered, her voice still strong although she could not hear it. "Last night your Dad came in and found the TV blasting. Someone had left the volume way up; I didn't hear a thing."

(Indeed, my father later explained, he recently tested her by sneaking up while she was reading and giving a loud clap just behind her ear. Her eye never wavered from the page.)

What is it like, I wondered. "A silent world?"

"Yes," she replied. "It's a silent world."
And for her, with human connections made difficult, it became a socially isolated world. “Not having understood what was said in a group,” she reminisced, “I would chime in and say the same thing someone else had just said—and everyone would laugh. I would be so embarrassed, I wanted to fall through the floor.” Increasingly, her way of coping was to avoid getting out onto the floor in the first place. She shied away from public events and found excuses to avoid people who didn’t understand.

Our exchange left me wondering. Will I—having inherited her progressive hearing loss—also become socially isolated? Or, aided by today’s better technology, can I keep my private vow not to repeat her past? Hearing allows mind-to-mind communication and enables connection. Yet many of us can and do connect despite hearing loss—with help from technology, lip-reading, and signing. For me, it’s worth the effort. Communicating with others affirms our humanity as social creatures.

So, how does hearing normally work? How do we harvest meaning from the air pressure waves sent from another’s mouth?

The Stimulus Input: Sound Waves

Draw a bow across a violin, and you will unleash the energy of sound waves. Jostling molecules of air, each bumping into the next, create waves of compressed and expanded air, like the ripples on a pond circling out from a tossed stone. As we swim in our ocean of moving air molecules, our ears detect these brief air pressure changes. (Exposed to a loud, low bass sound—perhaps from a bass guitar or a cello—we can also feel the vibration. We hear by both air and bone conduction.)

Like light waves, sound waves vary in shape. The amplitude of sound waves determines their loudness. Their length, or frequency, determines the pitch we experience. Long waves have low frequency—and low pitch. Short waves have high frequency—and high pitch. Sound waves produced by a violin are much shorter and faster than those produced by a cello or a bass guitar.

We measure sounds in decibels, with zero decibels representing the absolute threshold for hearing. Every 10 decibels correspond to a tenfold increase in sound intensity. Thus, normal conversation (60 decibels) is 10,000 times more intense than a 20-decibel whisper. And for her, with human connections made difficult, it became a socially isolated world.

The Ear

The intricate process that transforms vibrating air into nerve impulses, which our brain decodes as sounds, begins when sound waves enter the outer ear. A mechanical chain reaction begins as the visible outer ear channels the waves through the auditory canal to the eardrum, a tight membrane, causing it to vibrate (Figure 20.1 on the next page). In the middle ear three tiny bones (the malleus, incus, and stapes) pick up the vibrations and transmit them to the cochlea, a snail-shaped tube in the inner ear. The incoming vibrations cause the cochlea’s membrane (the oval window) to vibrate, jostling the fluid that fills the tube. This motion causes ripples in the basilar membrane, bending the hair cells lining its surface, not unlike the wind bending a wheat field. Hair cell movements trigger impulses in the adjacent nerve cells. Axons of these cells converge to form the auditory nerve, which sends neural messages (via the thalamus) to the auditory cortex in the brain’s temporal lobe. From vibrating air to fluid waves to electrical impulses to the brain: Voila! We hear.

The sounds of music: A violin’s short, fast waves create a high pitch, a cello’s longer, slower waves a lower pitch. Differences in the waves’ height, or amplitude, also create differing degrees of loudness. (To review the physical properties of light and sound waves, see Figure 18.2 in Module 18.)

ENGAGE

Applying Science

Have students measure the decibels of different sounds common to school: the bells that signal class changes, hall noise, and different teachers’ voices. Do these sounds fall within the safe range of decibels?

ENGAGE

Active Learning

Students can also demonstrate bone-conducted sound with a metal coat hanger tied to the center of a thin string about 4’ long. They should first press each end of the string into each ear with the tips of the index fingers while plugging their ears. Then they should ask someone to tap the coat hanger with a knife or fork. John Fisher reports that the effect will sound like the city of London’s famous clock Big Ben.
**ENGAGE**

**Enrichment**

Why does our own voice sound unfamiliar when we hear it on tape? When we listen to ourselves speak, we hear both the sound conducted by airwaves to the outer ear and that sound carried directly to the auditory nerve by bone conduction. The latter is easily demonstrated by clicking the teeth or munching popcorn, or by striking the prongs of a fork on a table and quickly applying its handle to the bone behind the ear. An even more resounding effect will be produced if the fork’s handle is clenched between the teeth. The strictly air-conducted sound that others normally hear (like a sound we hear when our voice is on tape) is thinner. Students can hear the sound waves conducted by bone if they plug their ears and talk in a normal voice.


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My vote for the most intriguing part of the hearing process is the hair cells—“quivering bundles that let us hear” thanks to their “extreme sensitivity and extreme speed” (Goldberg, 2007). A cochlea has 16,000 of them, which sounds like a lot until we compare that with an eye’s 130 million or so photoreceptors. But consider their responsiveness: Deflect the tiny bundles of cilia on the tip of a hair cell by the width of an atom—the equivalent of displacing the top of the Eiffel Tower by half an inch—and the alert hair cell, thanks to a special protein at its tip, triggers a neural response (Corey et al., 2004).

Be kind to your inner ear’s hair cells. When vibrating in response to sound, the hair cells shown here lining the cochlea produce an electrical signal.
Damage to the cochlea’s hair cell receptors or their associated nerves can cause sensorineural hearing loss (or nerve deafness). (A less common form of hearing loss is conduction hearing loss, caused by damage to the mechanical system that conducts sound waves to the cochlea.) Occasionally, disease causes sensorineural hearing loss, but more often the culprits are biological changes linked with heredity, aging, and prolonged exposure to ear-splitting noise or music.

Hair cells have been likened to carpet fibers. Walk around on them and they will spring back with a quick vacuuming. But leave a heavy piece of furniture on them for a long time and they may never rebound. As a general rule, if we cannot talk over a noise, it is potentially harmful, especially if prolonged and repeated (Roesser, 1998). Such experiences are common when sound exceeds 100 decibels, as happens in venues from frenzied sports arenas to bagpipe bands to personal music coming through our earphones near maximum volume (FIGURE 20.2).

Ringing of the ears after exposure to loud machinery or music indicates that we have been bad to our unhappy hair cells. As pain alerts us to possible bodily harm, ringing of the ears alerts us to possible hearing damage. It is hearing’s equivalent of bleeding.

The rate of teen hearing loss, now 1 in 5, has risen by one-third since the early 1990s (Shargorodsky et al., 2010). Teen boys more than teen girls or adults blast them selves with loud volumes for long periods (Zogby, 2006). Males’ greater noise exposure may help explain why men’s hearing tends to be less acute than women’s. But male or female, those who spend many hours in a loud nightclub, by one-third since the early 1990s (Shargorodsky et al., 2010). Teen boys more than teen girls or adults blast them selves with loud volumes for long periods (Zogby, 2006). Males’ greater noise exposure may help explain why men’s hearing tends to be less acute than women’s. But male or female, those who spend many hours in a loud nightclub, behind a power mower, or above a jackhammer should wear earplugs.

Ear muffs to protect the vulnerable hair cells of his son, Baylen. Victory amid pandemonium, he used ear muffs to protect the vulnerable hair cells of his son, Baylen. Brees celebrated New Orleans’ 2010 Super Bowl-winning quarterback Drew Brees celebrated New Orleans’ 2010 Super Bowl-winning quarterback Drew

People who are deaf due to a defect in either the inner or middle ear may still be able to hear by bone conduc tion. When Beethoven became deaf, he could still hear a piano being played by placing one end of his walking stick against it and gripping the other end between his teeth. To determine the nature and degree of their hearing loss, deaf violinists reportedly applied their teeth to some part of their vibrating instruments. If they could not hear sound, they concluded that the auditory nerves were the problem and the deafness was past cure.

**ENGAGE**

**Active Learning**

Loud music is often associated with teens, but how much dangerously loud noise are teens exposed to on a daily basis? Explore the following questions:

- How loud (in decibels) are the different levels of volume on a typical MP3 player? Do the manufacturers provide this information? Why or why not?
- Survey a group of teens who listen to MP3 players. At what level, on average, do they listen to their music?
- How loud is a typical concert? What do musicians do today to protect their hearing? Should concert promoters offer earplugs at the door of concerts? Why or why not?

**ENGAGE**

**Enrichment**

People in the Deaf community are divided over the roles of speech and sign language when communicating with the hearing world. Some in the community believe that learning to speak and read lips instead of learning sign language denies one’s identity as a Deaf person. Consider the following questions:

- What are the benefits and limitations of using sign language exclusively in a hearing world?
- What should the hearing world’s response be to the use of sign language?
For now, the only way to restore hearing for people with nerve deafness is a sort of bionic ear—a **cochlear implant**, which, by 2009, had been given to 188,000 people worldwide (NIDCD, 2011). This electronic device translates sounds into electrical signals that, wired into the cochlea’s nerves, convey information about sound to the brain. Cochlear implants given to deaf kittens and human infants seem to trigger an “awakening” of the pertinent brain area (Klinke et al., 1999; Sirenteanu, 1999). They can help children become proficient in oral communication (especially if they receive them as preschoolers or even before age 3) (Dettman et al., 2007; Schorr et al., 2005).

The latest cochlear implants also can help restore hearing for most adults. However, the implants will not enable normal hearing in adults if their brain never learned to process sound during childhood. Similarly, cochlear implants did not enable hearing in deaf-from-birth cats that received them when fully grown rather than as 8-week-old kittens (Ryugo et al., 2010).

**Perceiving Loudness**

How do we detect loudness? It is not, as I would have guessed, from the intensity of a hair cell’s response. Rather, a soft, pure tone activates only the few hair cells attuned to its frequency. Given louder sounds, neighboring hair cells also respond. Thus, the brain can interpret loudness from the number of activated hair cells.

If a hair cell loses sensitivity to soft sounds, it may still respond to loud sounds. This helps explain another surprise: Really loud sounds may seem loud to people with or without normal hearing. As a person with hearing loss, I used to wonder what really loud music must sound like to people with normal hearing. Now I realize it sounds much the same; where we differ is in our sensation of soft sounds. This is why we hard-of-hearing people do not want all sounds (loud and soft) amplified. We like sound compressed—which means harder-to-hear sounds are amplified more than loud sounds (a feature of today’s digital hearing aids).

**Perceiving Pitch**

How do we know whether a sound is the high-frequency, high-pitched chirp of a bird or the low-frequency, low-pitched roar of a truck? Current thinking on how we discriminate pitch, like current thinking on how we discriminate color, combines two theories.
Hermann von Helmholtz’s place theory presumes that we hear different pitches because different sound waves trigger activity at different places along the cochlea’s basilar membrane. Thus, the brain determines a sound’s pitch by recognizing the specific place (on the membrane) that is generating the neural signal. When Nobel laureate-to-be Georg von Békésy (1957) cut holes in the cochleas of guinea pigs and human cadavers and looked inside with a microscope, he discovered that the cochleas vibrated, rather like a shaken bedsheet, in response to sound. High frequencies produced large vibrations near the beginning of the cochlea’s membrane. Low frequencies vibrate more of the membrane, including near the end. But a problem remains: Place theory can explain how we hear high-pitched sounds but not low-pitched sounds. The neural signals generated by low-pitched sounds are not so neatly localized on the basilar membrane.

Frequency theory suggests an alternative: The brain reads pitch by monitoring the frequency of neural impulses traveling up the auditory nerve. The whole basilar membrane vibrates with the incoming sound wave, triggering neural impulses to the brain at the same rate as the sound wave. If the sound wave has a frequency of 100 waves per second, then 100 pulses per second travel up the auditory nerve. But again, a problem remains: An individual neuron cannot fire faster than 1000 times per second. How, then, can we sense sounds with frequencies above 1000 waves per second (roughly the upper third of a piano keyboard)?

Enter the volley principle: Like soldiers who alternate firing so that some can shoot while others reload, neural cells can alternate firing. By firing in rapid succession, they can achieve a combined frequency above 1000 waves per second. Thus, place theory best explains how we sense high pitches, frequency theory best explains how we sense low pitches, and some combination of place and frequency seems to handle the pitches in the intermediate range.

Locating Sounds

How do we locate sounds?

Why don’t we have one big ear—perhaps above our one nose? “All the better to hear you with,” as the wolf said to Red Riding Hood. As the placement of our eyes allows us to sense visual depth, so the placement of our two ears allows us to enjoy stereophonic (“three-dimensional”) hearing.

Two ears are better than one for at least two reasons. If a car to the right honks, your right ear receives a more intense sound, and it receives sound slightly sooner than your left ear (Figure 20.3). Because sound travels 750 miles per hour and our ears are but 6 inches apart, the intensity difference and the time lag are extremely small. A just noticeable difference in the direction of two sound sources corresponds to a time difference of just 0.000027 second! Lucky for us, our supersensitive auditory system can detect such minute differences (Brown & Doffenbacher, 1979; Middlebrooks & Green, 1991).

Active Learning

Invite a volunteer to sit with eyes closed in a chair facing the class. Clap at varying locations around the volunteer’s head. The person will confidently and accurately locate sounds coming from either side (which strike the 2 ears differently), but will have more difficulty locating sound in the 360° plane equidistant between the 2 ears (overhead, in back, or in front).

Teaching Tip

Ask students why dogs cock their heads to one side or another when they listen to sounds. Explain that dogs and other animals do that to identify the direction of the sound and hear it better.

Active Learning

We localize sound by detecting small differences in the loudness and timing of the sounds received by the 2 ears. Using a 4’ length of flexible plastic tubing or hose have a student hold each end of the tube up to each ear, while the circle formed is kept down and in front of the body. Another person then taps the tube with a pencil. A sound wave will move in both directions to the ears. If the tube is tapped at any point other than the middle, the sound will reach the 2 ears at different times. Thus, the sound will seem to come from different directions as different spots on the tube are struck. The perceived direction of a sound is related to differences in the time at which the sound is received by each ear.

What are the characteristics of air pressure waves that we hear as sound, and how does the ear transform sound energy into neural messages?

- Sound waves are bands of compressed and expanded air. Our ears detect these changes in air pressure and transform them into neural impulses, which the brain decodes as sound.
- Sound waves vary in amplitude, which we perceive as differing loudness, and in frequency, which we experience as differing pitch.
- The outer ear is the visible portion of the ear. The middle ear is the chamber between the eardrum and cochlea.
- The inner ear consists of the cochlea, semicircular canals, and vestibular sacs.
- Through a mechanical chain of events, sound waves traveling through the auditory canal cause tiny vibrations in the eardrum. The bones of the middle ear (the hammer, anvil, and stirrup) amplify the vibrations and relay them to the fluid-filled cochlea. Rippling of the basilar membrane, caused by pressure changes in the cochlear fluid, causes movement of the tiny hair cells, triggering neural messages to be sent (via the thalamus) to the auditory cortex in the brain.
- Sensorineural hearing loss (or nerve deafness) results from damage to the cochlea’s hair cells or their associated nerves. Conductive hearing loss results from damage to the mechanical system that transmits sound waves to the cochlea. Cochlear implants can restore hearing for some people.

What theories help us understand pitch perception?

- **Place theory** explains how we hear high-pitched sounds, and **frequency theory** explains how we hear low-pitched sounds. (A combination of the two theories (the volley principle) explains how we hear pitches in the middle range.)
- **Place theory** proposes that our brain interprets a particular pitch by decoding the place where a sound wave stimulates the cochlea’s basilar membrane.
- **Frequency theory** proposes that the brain deciphers the frequency of the neural impulses traveling up the auditory nerve to the brain.

How do we locate sounds?

- Sound waves strike one ear sooner and more intensely than the other. The brain analyzes the minute differences in the sounds received by the two ears and computes the sound’s source.
Hearing Module 20

Multiple-Choice Questions

1. What type of hearing loss is due to damage to the mechanism that transmits sound waves to the cochlea?
   a. Sensorineural  
   b. Window-related  
   c. Conductive  
   d. Cochlear  
   e. Basilar

2. Pitch depends on which of the following?
   a. Amplitude of a sound wave  
   b. Number of hair cells stimulated  
   c. Strength of nerve impulses traveling up the auditory nerve  
   d. Number of sound waves that reach the ear in a given time  
   e. Decibels of a sound wave

3. Which of the following reflects the notion that pitch is related to the number of impulses traveling up the auditory nerve in a unit of time?
   a. Place theory  
   b. Frequency theory  
   c. Valley principle  
   d. Sound localization  
   e. Stereophonic hearing

4. The three small bones of the ear are located in the
   a. cochlea  
   b. outer ear  
   c. inner ear  
   d. middle ear  
   e. auditory nerve

Practice FRQs

1. Describe two parts of the ear that transmit sound waves before they reach the hair cells.
   Answer
   Students may describe any two of the following:
   1 point: The eardrum, a tight membrane separating the middle ear from the outer ear.
   1 point: The three bones in the middle ear that transmit sound waves between the eardrum and the cochlea.
   1 point: The oval window, the point at which vibrations enter the cochlea.
   1 point: The cochlea, where the fluid inside vibrates and the hair cells are stimulated.

2. What roles do the outer, middle, and inner ear play in helping a person hear a song on the radio?
   (3 points)

Answers to Multiple-Choice Questions

1. c  
2. d  
3. b  
4. d  

Answer to Practice FRQ

1 point: Outer ear: Hearing begins here where sound is funneled by the ear down the auditory canal to the eardrum, which is the tight membrane that begins to vibrate.

1 point: Middle ear: This portion of the ear receives the vibrations from the eardrum and sends them to the 3 tiny bones (hammer, anvil, and stirrup), and passes the vibrations to the cochlea’s oval window.

1 point: Inner ear: The sound travels through the semicircular canal to the cochlea. The cochlea converts sound pressure impulses into electrical impulses, which are transmitted by the auditory nerve to the brain.
TEACH
TRM Discussion Starter
Use the Module 21 Fact or Falsehood? student activity from the TRM to introduce the concepts from this module.

ENGAGE
Enrichment
There are 2 types of skin, the largest organ in the human body:
- **Hairy skin** contains hair cells, which detect movement and pressure.
- **Glabrous skin** contains no hair cells, so the receptors in this type of skin are more sensitive. Glabrous skin is found mainly on the palms of the hands, bottoms of the feet, and on the lips.

ENGAGE
TRM Active Learning
The skin senses variations of cold and warm which, when combined, make something feel hot. Donald Mershon suggests a convenient demonstration that utilizes an ice cube tray (one that makes the very small cubes). First fill every other row in either direction with water and freeze. Then, being careful not to slop water to produce melting, fill the empty row with warm water. Have a student place his or her hand over the surface of the tray to feel the heat. Use Student Activity: Warm Plus Cold Equals Hot from the TRM to further demonstrate this concept.

Module 21
The Other Senses

Module Learning Objectives

- **21-1** Describe the sense of touch.
- **21-2** Discuss how we best understand and control pain.
- **21-3** Describe the senses of taste and smell.
- **21-4** Explain how we sense our body’s position and movement.
- **21-5** Describe how our senses interact.

Although our brain gives seeing and hearing priority in the allocation of cortical tissue, extraordinary happenings occur within our four other senses—our senses of touch, taste, smell, and body position and movement. Sharks and dogs rely on their extraordinary sense of smell, aided by large brain areas devoted to this system. Without our own senses of touch, taste, smell, and body position and movement, we humans would also be seriously handicapped, and our capacities for enjoying the world would be seriously diminished.

Touch

21-1 How do we sense touch?

Although not the first sense to come to mind, touch is vital. Right from the start, touch is essential to our development. Infant rats deprived of their mother’s grooming produce less growth hormone and have a lower metabolic rate—a good way to keep alive until the mother returns, but a reaction that stunts growth if prolonged. Infant monkeys allowed to see, hear, and smell—but not touch—their mother become desperately unhappy; those separated by a screen with holes that allow touching are much less miserable. As we will see in Module 46, premature human babies gain weight faster and go home sooner if they are stimulated by hand massage. As lovers, we yearn to touch—to kiss, to stroke, to snuggle. And even strangers, touching only the other’s forearms and separated by a curtain, can communicate anger, fear, disgust, love, gratitude, and sympathy at levels well above chance (Hertenstein et al., 2006).

Humorist Dave Barry may be right to jest that your skin “keeps people from seeing the inside of your body, which is repulsive, and it prevents your organs from falling onto the ground.” But skin does much more. Our “sense of touch” is actually a mix of distinct skin senses for pressure, warmth, cold, and pain. Touching various spots on the skin with a soft
hair, a warm or cool wire, and the point of a pin reveals that some spots are especially sensitive to pressure, others to warmth, others to cold, still others to pain. Other skin sensations are variations of the basic four (pressure, warmth, cold, and pain):

- Striking adjacent pressure spots creates a tickle.
- Repeated gentle stroking of a pain spot creates an itching sensation.
- Touching adjacent cold and pressure spots triggers a sense of wetness, which you can experience by touching dry, cold metal.
- Stimulating nearby cold and warm spots produces the sensation of hot (FIGURE 21.1).

Touch sensations involve more than tactile stimulation, however. A self-produced tickle produces less somatosensory cortex activation than does the same tickle from something or someone else (Blake et al., 1998). (The brain is wise enough to be most sensitive to unexpected stimulation.)

**Pain**

How can we best understand and control pain?

Be thankful for occasional pain. Pain is your body’s way of telling you something has gone wrong. Drawing your attention to a burn, a break, or a sprain, pain orders you to change your behavior—“Stay off that turned ankle!” The rare people born without the ability to feel pain may experience severe injury or ever die before early adulthood. Without the discomfort that makes us occasionally shift position, their joints fail from excess strain, and without the warnings of pain, the effects of unhealed infections and injuries accumulate (Nesse, 1991).

More numerous are those who live with chronic pain, which is rather like an alarm that won’t shut off. The suffering of those with persistent or recurring backaches, arthritis, headaches, and cancer-related pain, prompts two questions: What is pain? How might we control it?

**Understanding Pain**

Our pain experiences vary widely. Women are more pain sensitive than men are (Wicholiky, 2009). Individual pain sensitivity varies, too, depending on genes, physiology, experience, attention, and surrounding culture (Gatchel et al., 2007; Reimann et al., 2010).

Thus, feeling pain reflects both bottom-up sensations and top-down processes.

**Biological Influences**

There is no one type of stimulus that triggers pain as light triggers vision. Instead, there are different receptors—sensory receptors that detect hurtful temperatures, pressure, or chemicals (FIGURE 21.2 on the next page).

Although no theory of pain explains all available findings, psychologist Ronald Melzack and biologist Patrick Wall’s (1965, 1983) classic gate-control theory provides a useful model. The spinal cord contains small nerve fibers that conduct most pain signals, and larger fibers that conduct most other sensory signals. Melzack and Wall theorized that the spinal cord contains a neurological “gate.” When tissue is injured, the small fibers activate and open the gate, and you feel pain. Large-fiber activity closes the gate, blocking pain signals and preventing them from reaching the brain. Thus, one way to treat chronic pain is to told what to expect following surgery and to relax to reduce their pain, they needed fewer painkillers and were sent home 2.7 days earlier than a control group. Research also indicates that up to 35% of patients with pathological pain obtain relief from a placebo that contains no active ingredients. These examples show that there is more to pain than what stimulates the sense receptors.

**Concept Connections**

Pain is mainly governed by nerves known as “free nerve endings,” which are not directly connected to any specific nervous system. Pain seems to be regulated within its own system, working where needed to signal the body to a painful stimulus. Nervous systems are discussed in more detail in Unit III.

**Active Learning**

Some people are born without the ability to feel pain. Although this may seem like a great condition to have, it is actually horribly tragic. To understand the situation, explore the following questions in a class discussion:

- Why would it be bad not to feel pain? (Pain allows us to determine injury, sickness, and danger.)
- What might be the expected life span of someone who can’t feel pain? (People born with this condition do not generally live long past the teen years. They often die of normally painful illnesses that they don’t feel.)

**Engage Enrichment**

The gate-control theory of pain helps explain why people aren’t always aware of pain. Pain signals can be controlled by the brain. The brain can sometimes choose which pain to consider and which to ignore, blocking off pain signals in the spinal cord that it chooses to ignore. This theory explains why pain is related to the severity of the injury incurred and why athletes can ignore major injuries. Research indicates that when surgical patients were
The gate-control theory of pain may explain why acupuncture works. Acupuncture is the ancient Chinese practice of inserting needles into the skin at certain points to alleviate pain. This practice may work because the needles create a competing sensation that blocks the pain signals. The brain could also be releasing endorphins to counteract the numerous pain sensations that acupuncture creates, thus alleviating pain.

**ENGAGE**

Enrichment

Phantom limb sensations occur when a person feels the presence of a limb after it has been lost. At times, people can experience intense pain in a limb that is no longer there. Contact a surgeon who specializes in amputations to come in and discuss how doctors treat patients with phantom limb pain and sensations.
The psychological effects of distraction are clear in the stories of athletes who, focused on winning, play through the pain. We also seem to edit our memories of pain, which often differ from the pain we actually experienced. In experiments, and after medical procedures, people overlook a pain's duration. Their memory snapshots instead record two factors: their pain's peak moment (which can lead them to recall variable pain, with peaks, as worse [Stone et al., 2005]), and how much pain they felt at the end.

In one experiment, researchers asked people to immerse one hand in painfully cold water for 60 seconds, and then the other hand in the same painfully cold water for 60 seconds followed by a slightly less painful 30 seconds more (Kahneman et al., 1993). Which experience would you expect to recall as most painful? Curiously, when asked which trial they would prefer to repeat, most preferred the longer trial, with more net pain—but less pain at the end. Physicians have used this principle with patients undergoing colon exams—lengthening the discomfort by a minute, but lessening its intensity (Kahneman, 1999). Although the extended milder discomfort added to their net pain experience, patients experiencing this taper-down treatment later recalled the exam as less painful than did those whose pain ended abruptly. (If, at the end of a painful root canal, the oral surgeon asks if you’d like to go home or to have a few more minutes of milder discomfort, there’s a case to be made for prolonging your hurt.)

Our perception of pain also varies with our social situation and our cultural traditions. We tend to perceive more pain when others also seem to be experiencing pain (Symbaluk et al., 1997). This may help explain other apparent social aspects of pain, as when pockets of Australian keyboard operators during the mid-1980s suffered outbreaks of severe pain during typing or other repetitive work—without any discernible physical abnormalities (Gawande, 1998). Sometimes the pain in sprain is mainly in the brain—literally. When feeling empathy for another’s pain, a person’s own brain activity may partly mirror that of the other’s brain in pain (Singer et al, 2004).

Thus, our perception of pain is a biopsychosocial phenomenon (FIGURE 21.3): Viewing pain this way can help us better understand how to cope with pain and treat it.
Controlling Pain

If pain is where body meets mind—if it is both a physical and a psychological phenomenon—then it should be treatable both physically and psychologically. Depending on the type of symptoms, pain control clinics select one or more therapies from a list that includes drugs, surgery, acupuncture, electrical stimulation, massage, exercise, hypnosis, relaxation training, and thought distraction.

Even an inert placebo can help, by dampening the central nervous system’s attention and responses to painful experiences—mimicking analgesic drugs (Eippert et al., 2009; Wager, 2005). After being injected in the jaw with a stinging saltwater solution, men in one experiment received a placebo said to relieve pain, and they immediately felt better. Being given fake pain-killing chemicals caused the brain to dispense real ones, as indicated by activity in an area that releases natural pain-killing opiates (Scott et al., 2007; Zubieta et al., 2005). “Believing becomes reality,” noted one commentator (Thernstrom, 2006), as “the mind unites with the body.”

Another experiment pitted two placebos—fake pills and pretend acupuncture—against each other (Kaptchuk et al., 2006). People with persistent arm pain (270 of them) received either sham acupuncture (with trick needles that retracted without puncturing the skin) or blue cornstarch pills that looked like pills often prescribed for strain injury. A fourth of those receiving the nonexistent needle pricks and 31 percent of those receiving the pills complained of side effects, such as painful skin or dry mouth and fatigue. After two months, both groups were reporting less pain, with the fake acupuncture group reporting the greater pain drop.

Distracting people with pleasant images (“Think of a warm, comfortable environment”) or drawing their attention away from the painful stimulation (“Count backward by 3s”) is an especially effective way to activate pain-inhibiting circuits and to increase pain tolerance (Edwards et al., 2009). A well-trained nurse may distract needle-shy patients by chatting with them and asking them to look away when inserting the needle. For burn victims receiving excruciating wound care, an even more effective distraction comes from immersion in a computer-generated 3-D world, like the snow scene in FIGURE 21.4. Functional MRI (fMRI) scans reveal that playing in the virtual reality reduces the brain’s pain-related activity (Hoffman, 2004). Because pain is in the brain, diverting the brain’s attention may bring relief.

Treatments for pain include hypnosis, acupuncture, physiotherapy, ultrasound, biofeedback, relaxation, and electrical stimulation. Many clinics also use some form of behavioral treatment, which is based on the assumption that pain has become a learned behavior pattern that can be changed.

Concept Connections

Remind students about the importance of placebos in research, as discussed in Unit II. Having a “fake” treatment for your control condition (or at least a treatment that mimics the status quo) helps ensure that just getting treatment is not causing a difference in groups.

Some researchers believe that hypnosis, discussed in Unit V, can be effective in relieving pain. Others believe that hypnosis is just an elaborate way to distract people from obvious stimuli. Regardless of the method, diverting one’s attention from pain can be helpful in alleviating its effects.

Teaching Tip

Point out that Dennis Turk and his colleagues have defined 3 subtypes of people who are evaluated at pain centers.

- Dysfunctional patients report high levels of pain and psychological distress, believe they have little control over their lives, and are extremely inactive.
- Interpersonally distressed patients feel they have little social support and report that significant others don’t take their pain seriously.
- Adaptive copers report far less pain and social distress than people in the other 2 groups and continue to function at a relatively high level.

Concept Connections

The functional MRI scans on the right illustrate a lowered pain response when the patient is distracted. Functional activity in the brain is by no means normal during the pain experience. Distracting people with pleasant images (“Think of a warm, comfortable environment”) or drawing their attention away from the painful stimulation (“Count backward by 3s”) can powerfully distract attention, thus reducing pain and the brain’s response to painful stimulation. The fMRI scan on the right illustrates a lowered pain response when the patient is distracted.
Taste
How do we experience taste and smell?

Like touch, our sense of taste involves several basic sensations. Taste's sensations were once thought to be sweet, sour, salty, and bitter, with all others stemming from mixtures of these four (McBurney & Gent, 1979). Then, as investigators searched for specialized nerve fibers for the four taste sensations, they encountered a receptor for what we now know is a fifth—the savory meaty taste of umami, best experienced as the flavor enhancer monosodium glutamate (MSG), often used in Chinese and Thai food.

Evolutionary psychologists explain that tastes exist for more than our pleasure (see TABLE 21.1). Pleasurable tastes attracted our ancestors to energy- or protein-rich foods that enabled their survival. Aversion to tastes deterred them from new foods that might be toxic. We see the inheritance of this biological wisdom in today's 2- to 6-year-olds, who are typically fussy eaters, especially when offered new meats or bitter-tasting vegetables, such as spinach and Brussels sprouts (Cook et al., 2003). Meat and plant toxins were both potentially dangerous sources of food poisoning for our ancestors, especially for children. Given repeated small tastes of disliked new foods, children will, however, typically begin to accept them (Vardie et al., 2003). (Module 38 will explore cultural influences on our taste preferences.)

Taste is a chemical sense. Inside each little bump on the top and sides of your tongue are 200 or more taste buds, each containing a pore that catches food chemicals. Into each taste bud pore, 50 to 100 taste receptor cells project antenna-like hairs that sense food molecules. Some receptors respond mostly to sweet-tasting molecules, others to salty-, sour-, umami-, or bitter-tasting ones. It doesn't take much to trigger a response that alerts your brain's temporal lobe. If a stream of water is pumped across your tongue, the addition of a concentrated salty or sweet taste for but one-tenth of a second will get your attention (Kelling & Halpern, 1983). When a friend asks for "just a taste" of your soft drink, you can squeeze off the straw after a mere instant.

Taste receptors reproduce themselves every week or two, so when you burn your tongue with hot pizza, it hardly matters. However, as you grow older, the number of taste buds decreases, as does taste sensitivity (Cowart, 1981). (No wonder adults enjoy strong-tasting foods that children resist.) Smoking and alcohol use accelerate these declines. Those who lose their sense of taste report that foods taste like "straw" and is hard to swallow (Cowart, 2005). Essential as taste buds are, there's more to taste than meets the tongue.

Expectations can influence taste. When told a sausage roll was "vegetarian," people in one experiment found it decidedly inferior to its identical partner labeled "meat" (Allen et al., 2008). In another experiment, when adults were told that a wine cost $90 rather than its real $10 price, they reported it tasting better and a brain area that responds to pleasant experiences showed more activity (Flassmann et al., 2008).

The traditional "tongue map" showing how different regions of the tongue detect different tastes is not accurate. In the late 1800s, a German doctoral student studied the tongue's sensitivity to different tastes, which he plotted on a graph. The graph of his data was done "impressionistically," meaning he didn't rely on his actual data to create the graph. For over 75 years, scholars took his graph at face value, perpetuating the myth of the tongue map.

Smell
Life begins with an inhale and ends with an exhale. Between birth and death, you will daily inhale and exhale nearly 20,000 breaths of life-sustaining air, bathing your nostrils in a stream of scent-laden molecules. The resulting experiences of smell are strikingly intimate. You inhale something of whatever or whoever it is you smell.

Like taste, smell is a chemical sense. We smell something when molecules of a substance carried in the air reach a tiny cluster of 20 million receptor cells at the top of each

**TABLE 21.1 The Survival Functions of Basic Tastes**

<table>
<thead>
<tr>
<th>Taste</th>
<th>Indicates</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sweet</td>
<td>Energy source</td>
</tr>
<tr>
<td>Salty</td>
<td>Sodium essential to physiological processes</td>
</tr>
<tr>
<td>Sour</td>
<td>Potentially toxic acid</td>
</tr>
<tr>
<td>Bitter</td>
<td>Potential poisons</td>
</tr>
<tr>
<td>Umami</td>
<td>Proteins to grow and repair tissue</td>
</tr>
</tbody>
</table>

(Adapted from Cowart, 2005.)

**Try This** Impress your friends with your new word for the day: People unable to see are said to experience blindness. People unable to hear experience deafness. People unable to smell experience anosmia.

**ENGAGE**
**Enrichment**
Psychologists Marcia Pelchat and Patricia Pliner tested whether it is the novelty of a food or something else that prompts people to spurn it. They gave 2 groups of people identical foods. When the foods were accurately named (“chopped tomatoes” and “beefsteak”), the participants were quite willing to taste them. When the foods were referred to as “pendula fruit” and “langua steaks,” participants were far less cooperative.

**TEACH**
**Common Pitfalls**
The Other Senses

- **ENGAGE**
  **Enrichment**
  According to Linda Bartoshuk, taste buds are innervated by 2 cranial nerves: one carries taste and the other carries pain and touch. Supertasters perceive more pain from oral irritants including chili peppers, ethyl alcohol, and carbonation. Fat in food is also perceived as a touch sensation. If you’re a supertaster, you’re a super perceiver of fat in food.

- **ENGAGE**
  **Enrichment**
  In one study of infants, sweet substances elicited sucking and, in some cases, smiling. Sour tastes produced “lip pursing and wrinkling of the nose,” and bitter tastes prompted “opening of the mouth with the upper lip elevated and protrusion of the tongue.” These reactions make good evolutionary sense, because bitter or sour plants are often toxic, whereas the sweeter ones tend to be nutritious.
**Concept Connections**

As a link to neuroscience, inform students that smell is the only sense where the signals do not go directly to the thalamus before being processed. In fact, smell is processed near the prefrontal cortex before it is sent along, which may help explain why smell can trigger powerful memories because that part of the brain works with the limbic system to process emotional memories.

**Engage Enrichment**

Can we tell if a person is male or female on the basis of odor alone? Research indicates that we can:

- Patricia Wallace had blindfolded participants sniff a thoroughly washed hand, held ½" from their nose. They could discriminate male from female hands with over 80% accuracy. Female sniffers were more accurate than male sniffers.
- Richard Doty and his colleagues had college students assess breath odor of participants who sat on the other side of a partition and exhaled through a plastic tube. Most judges scored better than chance, and again females outperformed males.
- Mark Russel had first-year college students wear T-shirts for 24 hours, after which the shirts were individually placed in sealed containers. Each participant was then presented with 3 containers: 1 holding his or her own shirt, a second holding the shirt of an unknown female, and a third holding the shirt of an unknown male. The vast majority were able to identify their own shirt and which other shirts belonged to a male or female.

Odor molecules come in many shapes and sizes—so many, in fact, that it takes many different receptors to detect them. A large family of genes designs the 350 or so receptor proteins that recognize particular odor molecules (Miller, 2004). Linda Buck and Richard Axel (1991) discovered (in work for which they received a 2004 Nobel Prize) that these receptor proteins are embedded on the surface of nasal cavity neurons. As a key slips into a lock, so odor molecules slip into these receptors. Yet we don't seem to have a distinct receptor for each detectable odor. This suggests that some odors trigger a combination of receptors, in patterns that are interpreted by the olfactory cortex. As the English alphabet's 26 letters can combine to form many words, so odor molecules bind to different receptor arrays, producing the 10,000 odors we can detect (Malnic et al., 1999). It is the combinations of olfactory receptors, which activate different neuron patterns, that allow us to distinguish between the aromas of fresh-brewed and hours-old coffee (Zou et al., 2005). For humans, the attractiveness of smells depends on learned associations (Herr, 2001). As babies nurse, their preference for the smell of their mother's

**The sense of smell** (FIGURE 21.5). These olfactory receptor cells, waving like sea anemones on a reef, respond selectively—to the aroma of a cake baking, to a wisp of smoke, to a friend's fragrance. Instantly, they alert the brain through their axon fibers. Being an old, primitive sense, olfactory neurons bypass the brain's sensory control center, the thalamus.

Research has shown that even nursing infants and their mothers have a literal chemistry to their relationship: They quickly learn to recognize each other's scents (McCarthy, 1986). Aided by smell, a mother fur seal returning to a beach crowded with pups will find her own. Our human sense of smell is less acute than our senses of seeing and hearing. Looking out across a garden, we see its forms and colors in exquisite detail and hear a variety of birds singing, yet we smell little of it without sticking our nose into the blossoms.
breast builds. So, too, with other associations. As good experiences are linked with a particular scent, people come to like that scent, which helps explain why people in the United States tend to like the smell of wintergreen (which they associate with candy and gum) more than do those in Great Britain (where it often is associated with medicine). In another example of odors evoking unpleasant emotions, researchers frustrated Brown University students with a rigged computer game in a scented room (Henz et al., 2004). Later, if exposed to the same odor while working on a verbal task, the students’ frustration was rekindled and they gave up sooner than others exposed to a different odor or no odor.

Though it’s difficult to recall odors by name, we have a remarkable capacity to recognize long-forgotten odors and their associated memories (Engen, 1987; Schab, 1991). The smell of the sea, the scent of a perfume, or an aroma of a favorite relative’s kitchen can bring to mind a happy time. It’s a phenomenon the British travel agent chain Lunn Poly understands well. To evoke memories of lounging on sunny, warm beaches, the company once piped the aroma of coconut suntan oil into its shops (Fracassi, 2008).

Our brain’s circuitry helps explain an odor’s power to evoke feelings and memories (Figure 21.6). A hotline runs between the brain area receiving information from the nose and the brain’s ancient limbic centers associated with memory and emotion. Thus, when put in a foul-smelling room, people expressed harsher judgments of immoral acts (such as lying or keeping a found wallet) and more negative attitudes toward gay men (Inbar et al., 2011; Schnall et al., 2008).

**Body Position and Movement**

How do we sense our body’s position and movement?

Important sensors in your joints, tendons, and muscles enable your kinesthesia—your sense of the position and movement of your body parts. By closing your eyes or plugging your ears you can momentarily imagine being without sight or sound. But what would it be like to live without touch or kinesthetic sense—without, therefore, being able to sense the positions of your limbs when you wake during the night? Ian Waterman of Hampshire, England, knows. In 1972, at age 19, Waterman contracted a rare viral infection that destroyed his sense of movement and position. The biological gyroscopes for this sense of equilibrium are in your inner ear. The semicircular canals, which look like a three-dimensional pretzel (Figure 20.1a), and the vestibular sacs, which connect the canals with the cochlea, contain fluid that moves when your head rotates or tilts. This movement stimulates hairlike receptors, which send impulses to the brain. If all systems working together enable us to maintain balance. If students spin around a few times, then with their eyes closed. The latter is more difficult, because the vestibular and visual systems working together enable us to maintain balance. If students spin around a few times, then close their eyes, they will find it impossible to balance on one foot.

**ENGGAE**

Active Learning

Invite a local dance or figure skating instructor to come to class to discuss how dancers and figure skaters maintain their balance when completing those amazing spins and turns.
Myers suggests that the tastes of certain foods or drinks are indistinguishable if smell is impaired. Have students test this by bringing in pieces of apple and potato and cold coffee and a sports drink. Using a blind taste test, have students plug their noses so that no air can get into the nose and taste the different examples. They should not be able to tell the difference in the taste between the foods or drinks if smell is impaired.

**TEACH**

**TRM Teaching Tip**
Point out to students that vision and taste can also interact. Have students imagine how appetizing blue macaroni and cheese might taste. Or perhaps have them consider the tastiness of green mashed potatoes. Students may also expect that red-colored drinks may taste like strawberry or cherry flavor, but may be startled if the taste is grape or orange. The color of our food and drink can influence our expectations of how it might taste. Use Teacher Demonstration: Vision and Taste from the TRM to show how visual stimuli can influence how we perceive taste using gelatin.

**Engage**

**Active Learning**

Sensory interaction: the principle that one sense may influence another, as when the smell of food influences its taste.

Our senses are not totally separate information channels. In interpreting the world, our brain blends their inputs. Consider what happens to your sense of taste if you hold your nose, close your eyes, and have someone feed you various foods. A slice of apple may be indistinguishable from a chunk of raw potato. A piece of steak may taste like cardboard. Without their smells, a cup of cold coffee may be hard to distinguish from a glass of Gatorade. To savor a taste, we normally breathe the aroma through our nose—which is why eating is not much fun when you have a bad cold. Smell can also change our perception of taste. A drink’s strawberry odor enhances our perception of its sweetness. Even touch can influence taste. Depending on its texture, a potato chip “tastes” fresh or stale (Smith, 2011). This is sensory interaction at work—the principle that one sense may influence another. Smell + texture + taste = flavor.

Vision and hearing may similarly interact. An almost imperceptible flicker of light is more easily visible when accompanied by a short burst of sound (Kayser, 2007). And a sound may be easier to hear with a visual cue. If I (as a person with hearing loss) watch a video with simultaneous captioning, I have no trouble hearing the words I am seeing (and may therefore think I don’t need the captioning). If I then turn off the captioning, I suddenly realize I do need it. The eyes guide the ears. (Figure 21.7).

But what do you suppose happens if the eyes and the ears disagree? What if we see a speaker saying one syllable while we hear another? Surprise: We may perceive a third syllable that blends both inputs. Seeing the mouth movements for go while hearing he we may perceive de. This phenomenon is known as the McGurk effect, after its discoverers, psychologists Harry McGurk and his assistant John MacDonald (1976).

Touch also interacts with our other senses. In detecting events, the brain can combine simultaneous touch and visual signals, thanks to neurons projecting from the somatosensory cortex back to the visual cortex (Macaluso et al., 2000). Touch even interacts with hearing. In one experiment, researchers blew a puff of air (such as our mouths produce when saying pa and ta) on the neck or hands as people heard either these sounds or the more airless sounds ba or da. To my surprise (and yours?), the people more often misheard messages to the cerebellum at the back of the brain, thus enabling you to sense your body position and to maintain your balance. If you twirl around and then come to an abrupt halt, neither the fluid in your semicircular canals nor your kinesthetic receptors will immediately return to their neutral state. The dizzy aftereffect fools your brain with the sensation that you’re still spinning. This illustrates a principle that underlies perceptual illusions: Mechanisms that normally give us an accurate experience of the world can, under special conditions, fool us. Understanding how we get fooled provides clues to how our perceptual system works.
After holding a warm drink rather than a cold one, people are more likely to rate someone more warmly, feel closer to them, and behave more generously (IJzerman & Semin, 2009; Williams & Bargh, 2008). Physical warmth promotes social warmth.

After being given the cold shoulder by others in an experiment, people judge the room as colder than do those treated warmly (Zhong & Leonardielli, 2008). Social exclusion literally feels cold.

Holding a heavy rather than light clipboard makes job candidates seem more important. Holding rough objects makes social interactions seem more difficult (Ackerman et al., 2010).

When leaning to the left—by sitting in a left- rather than right-leaning chair, or squeezing a hand-grip with their left hand, or using a mouse with their left hand—people lean more left in their expressed political attitudes (Oppenheimer & Trail, 2010).

These examples of embodied cognition illustrate how brain circuits processing our bodily sensations connect with brain circuits responsible for cognition.

So, the senses interact: As we attempt to decipher our world, our brain blends inputs from multiple channels. For many people, an odor, perhaps of mint or chocolate, can evoke a sensation of taste (Stevenson & Tomiczek, 2007). But in a few select individuals, the senses become joined in a phenomenon called synesthesia, where one sort of sensation (such as hearing sound) produces another (such as seeing color). Thus, hearing music may activate color-sensitive cortex regions and trigger a sensation of color (Brang et al., 2008; Hubbard et al., 2005). Seeing the number 3 may evoke a taste sensation (Ward, 2003).

### Table 21.2 Summarizing the Senses

<table>
<thead>
<tr>
<th>Sensory System</th>
<th>Source</th>
<th>Receptors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vision</td>
<td>Light waves striking the eye</td>
<td>Rods and cones in the retina</td>
</tr>
<tr>
<td>Hearing</td>
<td>Sound waves striking the outer ear</td>
<td>Cochlear hair cells in the inner ear</td>
</tr>
<tr>
<td>Touch</td>
<td>Pressure, warmth, cold, pain on the skin</td>
<td>Skin receptors detect pressure, warmth, cold, and pain</td>
</tr>
<tr>
<td>Taste</td>
<td>Chemical molecules in the mouth</td>
<td>Basic tongue receptors for sweet, sour, salty, bitter, and umami</td>
</tr>
<tr>
<td>Smell</td>
<td>Chemical molecules breathed in through the nose</td>
<td>Millions of receptors at top of nasal cavity</td>
</tr>
<tr>
<td>Body position—kinesthesia</td>
<td>Any change in position of a body part, interacting with vision</td>
<td>Kinesthetic sensors all over the body</td>
</tr>
<tr>
<td>Body movement—vestibular sense</td>
<td>Movement of fluids in the inner ear caused by head/body movement</td>
<td>Hairlike receptors in the semi-circular canals and vestibular sacs</td>
</tr>
</tbody>
</table>

For a summary of our sensory systems, see Table 21.2. The river of perception is fed by sensation, cognition, and emotion. And that is why we need biological, psychological, and social-cultural levels of analysis.
**CLOSE & ASSESS**

Exit Assessment

Choose one of the concepts below that are often misunderstood and have students provide an explanation of that concept:

- Gate-control theory of pain
- Kinesthesia vs. vestibular sense
- Embodied cognition
- Synesthesia

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**Module 21 Review**

**21-1 How do we sense touch?**

- Our sense of touch is actually several senses—pressure, warmth, cold, and pain—that combine to produce other sensations, such as "hot."

**21-2 How can we best understand and control pain?**

- Pain reflects bottom-up sensations (such as input from nociceptors, the sensory receptors that detect hurtful temperatures, pressure, or chemicals) and top-down processes (such as experience, attention, and culture).
- One theory of pain is that a "gate" in the spinal cord either opens to permit pain signals traveling up small nerve fibers to reach the brain, or closes to prevent their passage.
- The biopsychosocial perspective views our perception of pain as the sum of biological, psychological, and social-cultural influences. Pain treatments often combine physical and psychological elements, including placebos and distractions.

**21-3 How do we experience taste and smell?**

- Taste and smell are chemical senses.
- Taste is a composite of five basic sensations—sweet, sour, salty, bitter, and umami—and of the aromas that interact with information from the taste receptor cells of the taste buds.
- Odor molecules trigger combinations of receptors, in patterns that the olfactory cortices interprets. The receptor cells send messages to the brain's olfactory bulb, then to the temporal lobe, and to parts of the limbic system.

**21-4 How do we sense our body's position and movement?**

- Through kinesthesia, we sense the position and movement of our body parts.
- We monitor our body's position and movement, and maintain our balance with our vestibular sense.

---

To feel awe, mystery, and a deep reverence for life, we need look no further than our own perceptual system and its capacity for organizing formless nerve impulses into colorful sights, vivid sounds, and evocative smells. As Shakespeare's Hamlet recognized, "There are more things in Heaven and Earth, Horatio, than are dreamt of in your philosophy." Within our ordinary sensory and perceptual experiences lies much that is truly extraordinary—surely much more than has so far been dreamt of in our psychology.

**ASK YOURSELF**

Have you ever experienced a feeling that you think could be explained by embodied cognition?

**TEST YOURSELF**

How does our system for sensing smell differ from our sensory systems for vision, touch, and taste?

Answers to the Test Yourself questions can be found in Appendix E at the end of the book.
How do our senses interact?

Our senses can influence one another. This sensory interaction occurs, for example, when the smell of a favorite food amplifies its taste.

Embodied cognition is the influence of bodily sensations, gestures, and other states on cognitive preferences and judgments.

Multiple-Choice Questions

1. Sensing the position and movement of individual body parts is an example of which sense?
   a. Kinesthetic
   b. Vestibular
   c. Auditory
   d. Umami
   e. Olfactory

2. Which of the following is the best example of kinesthesia?
   a. Awareness of the smell of freshly brewed coffee
   b. Ability to feel pressure on your arm
   c. Ability to hear a softly ticking clock
   d. Ability to calculate where a kicked soccer ball will land from the moment it leaves your foot
   e. Awareness of the position of your arms when swimming the backstroke

3. Which of the following is the best example of sensory interaction?
   a. Finding that despite its delicious aroma, a weird-looking meal tastes awful
   b. Finding that food tastes bland when you have a bad cold
   c. Finding it difficult to maintain your balance when you have an ear infection
   d. Finding that the cold pool water doesn’t feel so cold after a while
   e. All of these are examples.

4. Which of the following is most closely associated with hairlike receptors in the semicircular canals?
   a. Body position
   b. Smell
   c. Hearing
   d. Pain
   e. Touch

Practice FRQs

1. Describe the receptor cells for taste and smell.

   Answer
   1 point: Taste: Receptor cells in the tongue detect sweet, sour, salty, bitter, and umami.
   1 point: Smell: Olfactory cells line the top of the nasal cavity.

2. Briefly explain the biopsychosocial perspective on pain and pain treatment.

   Answer to Practice FRQ 2
   1 point: Pain is the sum of biological, psychological, and social-cultural influences, depending on our brain's interpretation of it, genetic differences, attention, expectations, presence of others, and empathy, among other things.

   1 point: Treatment combines physical (drugs) and psychological (placebo and distraction) elements.
Unit IV Review

Key Terms and Concepts to Remember

- sensation, p. 152
- perception, p. 152
- bottom-up processing, p. 152
- top-down processing, p. 152
- selective attention, p. 152
- inattentional blindness, p. 154
- change blindness, p. 154
- transduction, p. 155
- psychophysics, p. 155
- absolute threshold, p. 156
- signal detection theory, p. 156
- subliminal, p. 157
- priming, p. 157
- difference threshold, p. 158
- Weber's law, p. 158
- sensory adaptation, p. 159
- perceptual set, p. 163
- extrasensory perception (ESP), p. 167
- parapsychology, p. 167
- wavelength, p. 171
- hue, p. 172
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- lens, p. 172
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- accommodation, p. 172
- rods, p. 173
- cones, p. 173
- optic nerve, p. 173
- blind spot, p. 173
- fovea, p. 173
- feature detectors, p. 175
- parallel processing, p. 176
- Young-Helmholtz trichromatic (three-color) theory, p. 178
- opponent-process theory, p. 179
- gestalt, p. 182
- figure-ground, p. 183
- grouping, p. 183
- depth perception, p. 184
- visual cliff, p. 184
- binocular cues, p. 184
- retinal disparity, p. 184
- monocular cues, p. 185
- phi phenomenon, p. 185
- perceptual constancy, p. 186
- color constancy, p. 187
- perceptual adaptation, p. 191
- audition, p. 194
- frequency, p. 195
- pitch, p. 195
- middle ear, p. 195
- cochlea [KOHK-lee-uh], p. 195
- inner ear, p. 195
- sensorineural hearing loss, p. 197
- conduction hearing loss, p. 197
- cochlear implant, p. 198
- place theory, p. 199
- frequency theory, p. 199
- gate-control theory, p. 203
- kinesthesia [kin-ehs-THEE-see-a], p. 209
- vestibular sense, p. 209
- sensory interaction, p. 210
- embodied cognition, p. 211

Key Contributors to Remember

- Gustav Fechner, p. 156
- Ernst Weber, p. 158
- David Hubel, p. 175
- Torsten Wiesel, p. 175

AP® Exam Practice Questions

Multiple-Choice Questions

1. What is the purpose of the iris?
   - a. To focus light on the retina
   - b. To process color
   - c. To allow light into the eye
   - d. To enable night vision
   - e. To detect specific shapes

2. Neurons that fire in response to specific edges, lines, angles, and movements are called what?
   - a. Rods
   - b. Cones
   - c. Ganglion cells
   - d. Feature detectors
   - e. Bipolar cells

Answers to Multiple-Choice Questions

1. c, 2. d
3. Signal detection theory is most closely associated with which perception process?
   a. Vision  
   b. Sensory adaptation  
   c. Absolute thresholds  
   d. Smell  
   e. Context effects

4. Which of the following represents perceptual constancy?
   a. We recognize the taste of McDonald's food each time we eat it.
   b. In photos of people, the people almost always are perceived as figure and everything else as ground.
   c. We know that the color of a printed page has not changed as it moves from sunlight into shadow.
   d. From the time they are very young, most people can recognize the smell of a dentist's office.
   e. The cold water in a lake doesn't seem so cold after you have been swimming in it for a few minutes.

5. Our tendency to see faces in clouds and other ambiguous stimuli is partly based on what perception principle?
   a. Selective attention  
   b. ESP  
   c. Perceptual set  
   d. Shape constancy  
   e. Bottom-up processing

6. The process by which rods and cones change electromagnetic energy into neural messages is called what?
   a. Adaptation  
   b. Accommodation  
   c. Parallel processing  
   d. Transduction  
   e. Perceptual setting

7. Which of the following is most likely to influence our memory of a painful event?
   a. The overall length of the event  
   b. The intensity of pain at the end of the event  
   c. The reason for the pain  
   d. The amount of rest you've had in the 24 hours preceding the event  
   e. The specific part of the body that experiences the pain

8. Frequency theory relates to which element of the hearing process?
   a. Rate at which the basilar membrane vibrates  
   b. Number of fibers in the auditory nerve  
   c. Point at which the basilar membrane exhibits the most vibration  
   d. Decibel level of a sound  
   e. Number of hair cells in each cochlea

9. Which of the following best represents an absolute threshold?
   a. A guitar player knows that his D string has just gone out of tune.
   b. A photographer can tell that the natural light available for a photograph has just faded slightly.
   c. Your friend amazes you by correctly identifying unlabeled glasses of Coke and Pepsi.
   d. A cook can just barely taste the salt she has added to her soup.
   e. Your mom throws out the milk because she says the taste is "off."

10. Which of the following describes a perception process that the Gestalt psychologists would have been interested in?
    a. Depth perception and how it allows us to survive in the world
    b. Why we see an object near us as closer rather than larger
    c. How an organized whole is formed out of its component pieces
    d. What the smallest units of perception are
    e. The similarities between shape constancy and size constancy

11. Which perception process are the hammer, anvil, and string involved in?
    a. Processing intense colors  
    b. Processing information related to our sense of balance  
    c. Supporting a structural frame to hold the eardrum  
    d. Transmitting sound waves to the cochlea  
    e. Holding hair cells that enable hearing

12. Which of the following might result from a disruption of your vestibular sense?
    a. Inability to detect the position of your arm without looking at it  
    b. Loss of the ability to detect bitter tastes  
    c. Dizziness and a loss of balance  
    d. An inability to detect pain  
    e. Loss of color vision

13. When we go to the movies, we see smooth continuous motion rather than a series of still images because of which process?
    a. The phi phenomenon  
    b. Perceptual set  
    c. Stroboscopic movement  
    d. Relative motion  
    e. Illusory effect

Rubric for Free-Response Question 2

1 point: Gate-control theory describes how pain is experienced: Pain "gates" open or close, determining which sensations might be perceived (or not perceived) as pain. In this scenario, Ester might experience pain when she runs into the doorway due to gate-control theory.  

1 point: Ester's vestibular sense was involved as she stumbled and fell. Our vestibular sense helps us maintain our balance. We receive balance information from hair cells in our inner ear about our orientation in space.

1 point: Selective attention determines which sensations we will perceive and attend to. In this situation, Ester's selective attention system switches her attention to the shadowy figure, causing her to perceive it and act. After Ester notices this figure, she focuses on this situation, possibly not perceiving many other sensations as she focuses on catching the mystery figure.

1 point: Signal detection theory predicts when we will perceive weak or faint sensations. In this scenario, Ester detected the weak signal of someone suddenly ducking into a doorway.

1 point: Binocular cues are one of the principle ways we perceive depth and distance with both eyes. Something may have gone wrong with binocular cues for Ester in this situation because she misjudged the distance to the doorway and ran into it.

1 point: Perceptual set is a mental expectation or assumption about how we should perceive a set of sensations. In this scenario, Ester had a powerful perceptual set for her roommate, immediately recognizing her in the end.

Review  Unit IV  215
Answers to Multiple-Choice Questions

14. a  15. b

Rubric for Free-Response Question 3
(Note: Students should include the terms in some logical “beginning to end” order, which will likely be different from the order in which the points are listed below.)

1 point: Transduction occurs when light energy is transformed into neural signals in the eye (specifically, in the retina). In this situation, light reflected off the page (or screen) enters the eye and is changed into neural signals. **C** p. 155

1 point: Top-down processing occurs as we read this text. We use our expectations and prior experience (specifically, the shapes of letters and our knowledge of words) to read the text and make meaning. **C** p. 152

1 point: Light bounces off the page or screen and enters the eye. This image is projected on the retina in the back of the eye. Neurons in the retina fire in response to stimulation from this light, starting the process of transduction. **C** p. 172

1 point: The image of the text enters the eye through the pupil, a hole in the front of the eye. **C** p. 172

1 point: Neural messages from the optic nerve end up in the occipital lobe, where the brain makes sense of the image (using feature detectors). Visual perception occurs in the occipital lobe. **C** pp. 174–175

1 point: Rods are specialized neurons in the retina that fire in response to black and white images (such as black text against a white background on a page or screen). **C** p. 173

1 point: Feature detectors are specialized groups of neurons in the occipital lobe that fire in response to specific visual features, such as curves, angles, or shapes. Feature detectors in our occipital lobes fire in response to the curves and shapes of letters, beginning the perception process that ends with our perception of words on the page or screen. **C** p. 175

Free-Response Questions

1. While listening to the orchestra as she dances the lead role in Swan Lake, a ballerina concludes her performance with a pirouette, spinning around several times before leaping into the arms of her dance partner. Discuss how the ballerina relied on the following and how each is important.

   - Kinesthetic sense
   - Vestibular sense
   - Semicircular canals
   - Hearing

Rubric for Free Response Question 1

1 point: Kinesthesis will allow the ballerina to sense the position of different parts of her body as she dances the role. Thus, she will know that she is to start by facing the audience and, although she has spun around several times, she will always be aware of where the audience is, and where to put her feet and arms in order to accomplish the choreography. **C** Page 209

1 point: The vestibular sense enables the dancer to sense her body position and to maintain her balance. **C** Pages 209–210

1 point: Semicircular canals near her inner ear help the ballerina maintain her sense of balance. She needs this balance as she leaps and spins, and her training allows her to use her vestibular sense to maintain balance rather than become dizzy. **C** Pages 185 and 209

1 point: The ballerina’s sense of hearing allows her to perceive the music and to dance to the correct rhythm of each piece of music. **C** Pages 194–199

14. Two monocular depth cues are most responsible for our ability to know that a jet flying overhead is at an elevation of several miles. One cue is relative size. What is the other?

   a. Relative motion
   b. Retinal disparity
   c. Interposition
   d. Light and shadow
   e. Linear perspective

15. Which of the following phrases accurately describes top-down processing?

   a. The entry-level data captured by our various sensory systems
   b. The effect that our experiences and expectations have on perception
   c. Our tendency to scan a visual field from top to bottom
   d. Our inclination to follow a predetermined set of steps to process sound
   e. The fact that information is processed by the higher regions of the brain before it reaches the lower brain systems

2. Ester is walking to her chemistry class when she notices someone in the distance suddenly duck into a dark doorway. She is suspicious and starts to chase the figure, but misjudges the distance and accidentally runs into the door. She falls down but quickly recovers, and laughs when she discovers that the mystery person is her roommate, who was avoiding Ester, because she had borrowed Ester’s favorite sweater without permission and was afraid Ester might be angry. Use the following terms to explain the perceptual processes involved in this scenario.

   - Gate-control theory
   - Vestibular sense
   - Selective attention
   - Signal detection theory
   - Binocular cues
   - Perceptual set

   (6 points)

3. Describe, from the beginning of the process to the end, how your brain is perceiving the words you are reading right now. Use the following terms in your answer.

   - Transduction
   - Top-down processing
   - Retina
   - Pupil
   - Semicircular canals
   - Vestibular sense
   - Feature detectors

   (7 points)