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 knees-deep in motionless flies. But let one zoom by and the frog's "bug detector" cells snap awake.
- Male silkworm moths' 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

**Module Learning Objectives**

1. **16-1** Contrast sensation and perception, and explain the difference between bottom-up and top-down processing.
2. **16-2** Discuss how much information we can consciously attend to at once.
3. **16-3** Identify the three steps that are basic to all our sensory systems.
4. **16-4** Distinguish between absolute and difference thresholds, and discuss whether we can sense and be affected by stimuli below the absolute threshold.
5. **16-5** Explain the function of sensory adaptation.
16-1 What are sensation and perception? What do we mean by bottom-up processing and top-down processing?

Sellers' curious mix of "perfect vision" and face blindness illustrates the distinction between sensation and perception. When she looks at a friend, her sensation is normal: Her sensory system detects the same information years would, and they transmit that information to her brain. And her perception—the processes by which her brain organizes and interprets sensory input—is almost normal. Thus, she may recognize people from their hair, gait, voice, or particular posture, just not their face. Her experience is much like the struggle you or I would have trying to recognize a specific pigeon in a group of waddling penguins.

In our everyday experience, sensation and perception blend into one continuous process. In this module, we slow down that process to study its parts, but in real life, our sensory and perceptual processes work together to help us decipher the world around us.

- Our **bottom-up processing** starts at the sensory receptors and works up to higher levels of processing.
- Our **top-down processing** constructs perceptions from the sensory input by drawing on our experience and expectations.

As our brain absorbs the information in Figure 16.1, bottom-up processing enables our sensory systems to detect the lines, angles, and colors that form the flower and leaves. Using top-down processing, we interpret what our senses detect.

But how do we do it? How do we create meaning from the blizzard of sensory stimuli bombarding our bodies 24 hours a day? Meanwhile, in a silent, cushioned, inner world, our brain flounders in utter darkness. By itself, it sees nothing. It hears nothing. It feels nothing. So, how does the world out there get in? To phrase the question scientifically: How do we construct our representations of the external world? How do we turn a complex's flicker, cadence, and smoke scent activate neural connections? And how, from this living neurochemistry, do we create our conscious experience of the fire's motion and temperature, its aroma and beauty? In search of answers to such questions, let's look at some processes that cut across all our sensory systems. To begin, where is the border between our conscious and unconscious awareness, and what stimuli cross that threshold?

**Selective Attention**

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

Through selective attention, your awareness focuses, like a flashlight beam, on a minute aspect of all that you experience. By one estimate, your five senses take in 11,000,000 bits of information per second, of which you consciously process about 40 (Wilson, 2003). Yet your mind's unconscious track intuitively makes great use of the other 10,999,960 bits. Until reading this sentence, for example, you have been unaware that your shoes are pressing against your feet or that your nose is in line of vision. Now, suddenly, your attentional spotlight shifts. Your feet feel strange, your nose suddenly intrudes on the words before you. While focusing on these words, you've also been blocking other parts of your environment from awareness, though your peripheral vision would let you see them easily. You can change that. As you stare at the X below, notice what surrounds these sentences (the edges of the page, the desktop, the floor).

X

A classic example of selective attention is the cocktail party effect—your ability to attend to only one voice among many (while also being able to detect your own name in an unattended voice). This effect might have prevented an embarrassing and dangerous situation in 2009, when two commercial airline pilots "lost track of time." Focused on their laptops and conversation, they ignored alarming air traffic controllers' attempts to reach them as they overflew their Minneapolis destination by 150 miles. If only the controllers had known and asked the pilots' names.

**Selective Attention and Accidents**

Text 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 you, 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 (VTI, 2009). Mindful of such findings, the United States in 2010 banned truckers and bus drivers from texting while driving (Isley, 2010).

It's not just truck drivers who are at risk. One in four teen drivers with cell phones admit to texting while driving (Pesc, 2009). Multitasking comes at a cost: BMI 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 in which drivers to pull off at a freeway rest 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 (Grayer & Drews, 2007).

**AP® Exam Tip**

You may wish to think about how the information on selective attention relates to something a little less dangerous, but no less important—your study skills. 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 revisit yourself with a few minutes of social networking.

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*Sally Borth, "I was building this ship in a bottle."

*Driver to distraction* 
In a driving-simulation experiment, participants' selective attention is diverted by cell-phone conversation, making more driving errors.
Most European countries and American states now ban hand-held cell phones while driving (Hennessy, 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-assc, researchers Daniel Simons and Christopher Chabris (1999) sent a gorilla-suited assistant through the swirl of players. During its 9- 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 engaged 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-bending 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, 2011; 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.

**Figure 16.2**
Testing selective attention. In this classic experiment, viewers who were attending to basketball actions usually failed to notice the umbrellatognor woman sauntering across the screen. (From Neisser, 1979)

**Figure 16.3**
Change blindness. While a man (white hat) provides directions to a construction worker, two experimenters subtly pass between them. During the interruption, the original worker switches places with another person wearing different-colored clothing. Most people, focused on their direction giving, do not notice the switch.

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. Poised by trick jats the figure (FIGURE 16.4), most people didn’t notice that they were actually "retesting" their unpreferred 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.

**Figure 16.4**
Marketplace magic. Park an researchers Lenni Hall, Peter Johansson, and colleagues (2010) invited people to sample two jars and pick one to rotate. By tipping the jars after putting the lid back on, the researchers actually knocked people to "resemble" their nonchosen jam. Yet, even when asked whether they noticed anything odd, most testers were clueless blind. Even when given mildly different jars, they usually failed to notice the switch.

Transduction

16-3 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. All our senses • receive sensory stimulation, often using specialized receptor cells, • transform that stimulation into neural impulses, and • 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 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.

**Figure 16.3**
Change blindness. While a man (white hat) provides directions to a construction worker, two experimenters subtly pass between them. During the interruption, the original worker switches places with another person wearing different-colored clothing. Most people, focused on their direction giving, do not notice the switch.

**Figure 16.4**
Marketplace magic. Park an researchers Lenni Hall, Peter Johansson, and colleagues (2010) invited people to sample two jars and pick one to rotate. By tipping the jars after putting the lid back on, the researchers actually knocked people to "resemble" their nonchosen jam. Yet, even when asked whether they noticed anything odd, most testers were clueless blind. Even when given mildly different jars, they usually failed to notice the switch.

transduction: conversion of one form of energy into another. In sensation, the transforming of stimulus energies, such as sights, sounds, and smells, into neural impulses our brain can interpret.

psychophysics: the study of the relationship between the physical characteristics of stimuli, such as their intensity, and our psychological experience of them.
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 echoes 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 failing 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 16.8). Signal detection theorists seek to understand why people respond differently to the same stimulus (have you ever noticed that some teachers are much more likely than others to detect students testing during class?) and why the same person’s reactions vary as circumstances change. Exhausted 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).

Try This

Try out this old riddle on a couple of friends. "You’re driving a bus with 12 passengers. At your first stop, 6 passengers get off. At the second stop, 3 get off. At the third stop, 2 more get off but 3 new people get on. What color are the bus driver’s says?" Do your friends detect the signal—who is the bus driver—amid the accompanying noise?

Figure 16.5

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

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 unperceived 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 (bunnies, a romantic couple) or negative scenes (a werewolf, a dead body) an instant before participants viewed slides of people (Kensmreck et al., 1992). The participants consciously perceived either scene as only a flash of light. Yet the people somehow looked righter if their image immediately followed unperceived bunnies rather than an unperceived werewolf. 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 (Blumberg et al., 2003; Haynes & Rees, 2005, 2006). Only when the stimulus triggers synchronized activity in several brain areas does it reach consciousness (Deshazer, 2019). Once again we see the dual-track mind at work. Much of our information processing occurs automatically, out of sight, off the radar screen of our conscious mind.

So can we be controlled by subliminal messages? For more on that question, see Thinking Critically About: Can Subliminal Messages Control Our Behavior? on the next page.

Difference Thresholds

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 ears all sound alike to my ears. But not to those of ewes, which I have observed shearing, directly to the last of their lamb amid the chorus of other distressed lambs.
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 taste 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 suggestive powers. Can we do this? Yes, we can.

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 subtler, fleeting effect. Printing thirty words with the subliminal word thirst might therefore, for a moment, make a thirst-quenching beverage ad more persuasive (Shahan et al., 2003). Likewise, printing thirty words with Lipton ice tea may increase their consumption of the named brand (Kamenars et al., 2006; Velkamp et al., 2011; Vrenérjensen et al., 2011a,b). But the subliminal-message hucksters claim something different: a powerful, enduring effect on behavior.

To test whether subliminal recordings have this enduring effect, researchers randomly assigned university students to listen daily for 1-2 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 testimonial that once came 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, 1992). And placebo, you may remember, work only because we believe they will work.


difference threshold: the minimum difference between two stimuli required for detection 60 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 absolute amount).

Sensory Adaptation

16-5 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 nerves cease 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 are at an object without flikching, 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-receptors continues unchanged (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
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 relatively 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 internally on one task, we often display inattentive blindness (including change blindness) to other events and changes around us.

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

- Our sensors (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.

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 amidst 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 tastes) focuses our attention on informative changes in our environment.

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

Before You Move On

ASK YOURSELF

Can you recall a recent time when your attention focused on one thing, you were obvious 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 F at the end of the book.