Philippe Petit, famous high-wire artist, demonstrates his extraordinary sense of balance walking between two buildings.

Our Body Senses: Touch, Body Position, and Balance

4.9 Describe the three different body senses.

4.10 Explain how pain perception differs from touch perception.

4.11 Describe the field of psychology called human factors.

Using only the chalk on his hands and climbing shoes, Alain Roberts, nicknamed "The French Spiderman," has scaled the world's tallest skyscrapers. To do so, he must rely on his senses of touch, body position, and balance. One miscalculation, one slip of his foot or his hand, and he would plummet from the heights of buildings more than 80 stories tall.

Fortunately for Roberts, he, like the rest of us, has three body senses that work in tandem. The system we use for touch and pain is the **somatosensory** (*somato-,* for "body") system. We also have a body position sense, called *proprioception*, or kinesthetic sense, and a sense of equilibrium or balance, called the *vestibular sense*.

The Somatosensory System: Touch and Pain

The stimuli that activate the somatosensory system come in a variety of types. In this respect, this sense differs from vision and audition, each of which is devoted mainly to a single stimulus type.

PRESSURE, TEMPERATURE, AND INJURY. Our somatosensory system responds to stimuli applied to the skin, such as light touch or deep pressure, hot or cold temperature, or chemical or mechanical (touch-related) injury that produces pain. Somatosensory stimuli can be very specific, such as the embossed patterns of a letter written in Braille, or generalized to a large area of the body. Damage to internal organs sometimes causes "referred pain"—pain in a different location—such as an ache felt throughout the left arm and shoulder during a heart attack.

SPECIALIZED AND FREE NERVE ENDINGS IN THE SKIN. We sense light touch, deep pressure, and temperature with specialized nerve endings located on the ends of sensory nerves in the skin (see **FIGURE 4.21**). We also sense touch, temperature, and especially pain with *free nerve endings*, which are far more plentiful than specialized nerve endings. Nerve endings of all types are distributed unevenly across our body surface. Most of them are in our fingertips (which explains why it really stings when we cut our finger, say, in a paper cut), followed by our lips, face, hands, and feet. We have the fewest in the middle of our backs, perhaps explaining why even a strenuous deep back massage rarely makes us scream in agony.

HOW WE PERCEIVE TOUCH AND PAIN. Information about body touch, temperature, and painful stimuli travels in our somatic nerves before entering the spinal cord. Touch information travels more quickly than information about pain stimuli. Many of us have discovered this fact when stubbing our toes on a piece of furniture: We first feel our toes hitting the furniture, but don't experience the stinging pain (ouch!) until a second or two later. That's because touch and pain have different functions. Touch informs us of our immediate surroundings, and keys us into urgent matters, such as when something feels hot to avoid a serious burn, whereas pain alerts us to take care of injuries, which can often wait a little while.

Often touch and pain information activate local spinal reflexes before traveling to brain sites dedicated to perception (see Chapter 3). In some cases, painful stimuli trigger the withdrawal reflex. When we touch a fire or hot stove, we pull away immediately to avoid getting burned.

After activating spinal reflexes, touch and pain information travels upward through parts of the brain stem and thalamus to reach the somatosensory cortex (Bushnell et al., 1999). Additional cortical areas are active during the localization of touch information, such as association areas of the parietal lobe.

Factoid

Consuming ice cream or other cold substances too quickly doesn't cause pain in our brains. "Brain freeze," as it's sometimes called, doesn't affect the brain at all. It's produced by a constriction of blood vessels in the roof of our mouths in response to intense cold temperatures, followed by an expansion of these blood vessels, producing pain.

somatosensory
our sense of touch, temperature, and pain

As we've all discovered, pain comes in many varieties: sharp, stabbing, throbbing, burning, and aching. Many of the types of pain perception relate to the pain-causing stimulus—thermal (heat-related), chemical, or mechanical pain can also be acute, that is, short-lived, or chronic, that is, enduring, perhaps even lasting years. Each kind of pain-producing stimulus has a *threshold,* or point at which we perceive it as painful. People differ in their pain thresholds. Surprisingly, one study showed that people with naturally red hair require more anesthetic than do people with other hair colors (Liem et al., 2004). Of course, this correlational finding doesn't mean that red hair causes lower pain thresholds. Instead, some of the differences in people's thresholds are probably due to genetic factors that happen to be associated with hair color.

◀ **CORRELATION VS. CAUSATION**
Can we be sure that A causes B?

We can't localize pain as precisely as touch. Moreover, pain has a large emotional component. That's because pain information goes partly to the somatosensory cortex and partly to limbic centers in the brain stem and forebrain. The experience of pain is frequently associated with anxiety, uncertainty, and helplessness.

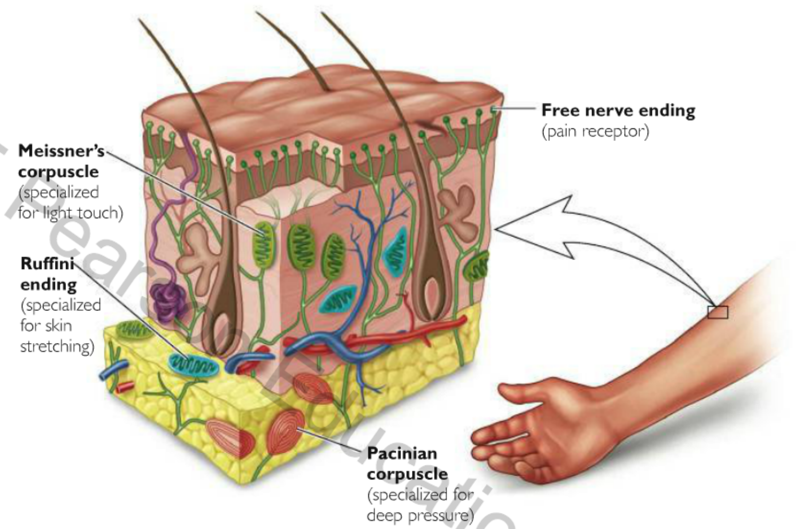
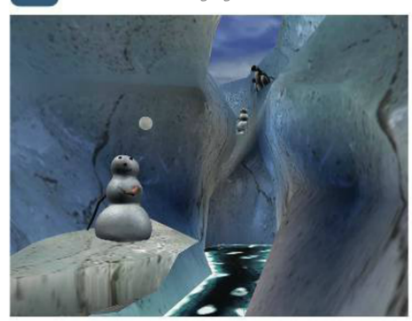


FIGURE 4.21 The Sense of Touch. The skin contains many specialized and free nerve endings that detect mechanical pressure, temperature, and pain.

Scientists believe we can control pain in part by controlling our thoughts and emotions in reaction to painful stimuli (Moore, 2008). This belief has been bolstered by stories of people withstanding excruciating pain during combat or natural childbirth. According to the **gate control model** of Ronald Melzack and Patrick Wall (1965, 1970), pain under these circumstances is blocked from consciousness because neural mechanisms in the spinal cord function as a "gate," controlling the flow of sensory input to the central nervous system. The gate-control model can account for how pain varies from situation to situation depending on our psychological state. Most of us have experienced becoming so absorbed in an event, such as an interesting conversation or television program, that we forgot about the pain we were feeling from a headache or a trip to the dentist's office. The gate control model proposes that the stimulation we experience competes with and blocks the pain from consciousness. Because pain demands attention, distraction is an effective way of short-circuiting painful sensations (Eccleston & Crombez, 1999; McCaul & Malott, 1984). For example, scientists discovered that they could relieve the pain of burn patients undergoing physical therapy, wound care, and painful skin grafts by immersing them in a virtual environment populated by snowmen and igloos (Hoffman & Patterson, 2005). On the flip side, when people dwell on catastrophic thoughts about pain (such as "I won't be able to bear it") it can open the floodgates of distress.

gate control model
idea that pain is blocked or gated from consciousness by neural mechanisms in spinal cord

Watch in **MyPsychLab** the **Video:** In the Real World: Managing Pain



Why do you think the designers of this virtual world chose imagery of snowmen and igloos for burn patients? What imagery would you choose, and why?

What's the evidence for the involvement of the spinal cord in the gate control model? Patrick Wall (2000) showed that the brain controls activity in the spinal cord, enabling us to turn up, damp down, or in some cases ignore pain. The placebo effect exerts a strong response on subjective reports of pain (see Chapter 3). Falk Eippert and his colleagues (Eippert et al., 2009) used brain imaging to demonstrate that pain-related activity in the spinal cord is sharply reduced when participants receive an application of a placebo cream they're told would alleviate pain. Placebos may also stimulate the body's production of its natural painkillers: endorphins (see Chapter 3; Glasser & Frishman, 2008). Scientists are investigating ways of boosting endorphins while deactivating glial cells in the spinal cord that amplify pain (Bartley, 2009; Watkins & Maier, 2002) (see Chapter 3).

For many years the scientific consensus has been that we can ignore pain, or at least withstand it, with a stoic mind-set (Szasz, 1989). There's evidence that people of certain cultural backgrounds, such as American Indians, Cambodians, Chinese, and Germans, are more reserved and less likely to communicate openly about pain, whereas South and Central Americans consider it more acceptable to moan and cry out when in pain (Ondeck, 2003). Although these descriptions of average behavior may help physicians deal with diverse populations, the premise that pain perception varies with ethnicity isn't universally accepted. An alternative hypothesis is that health care professionals treat certain ethnic groups differently. Blacks and Hispanics are less likely than Caucasians to receive analgesic (anti-pain) medication during emergency room visits (Bonham, 2001), which could account for some of the differences in reports of pain.

RULING OUT RIVAL HYPOTHESES ▶ Have important alternative explanations for the findings been excluded?

Are there any unusual activities for which a stoic mind-set may come in handy? Some popular psychology gurus certainly think so. Firewalkers, popular in India, Japan, North Africa, and the Polynesian islands, have walked 20- to 40-foot-long beds of burning embers. Although the practice has been around since as early as 1200 B.C., there's recently been a glut of "Firewalking Seminars" in California, New York, and other states. These motivational classes promise ordinary people everything from heightened self-confidence to spiritual enlightenment—all by walking down an 8- to 12-foot-long path of burning embers. Contrary to what we might learn at these seminars, success in firewalking has nothing to do with pain sensitivity and everything to do with physics. The type of coal or wood used in firewalking has a low rate of heat exchange, such that it burns red hot in the center while remaining less hot on the outside (Kurtus, 2000). So any of us can firewalk successfully just so long as we walk (or even better, run) over the burning embers quickly enough. Still, accidents can occur if the fire isn't prepared properly or if the firewalker walks too slowly.

Although firewalking seminars are extremely popular, there is nothing magical or mysterious about firewalking—but don't try it at home.

PHANTOM LIMB ILLUSION. Persons with amputated limbs often experience the eerie phenomenon of **phantom pain**, pain or discomfort in the missing limb. About 50 to 80 percent of amputees experience phantom limb sensations (Pühse et al., 2010; Sherman, Sherman, & Parker 1984). The missing limb often feels as if it's in an uncomfortably distorted position.

Vilayanur Ramachandran and colleagues developed a creative treatment for phantom limb pain called the *mirror box* (Ramachandran & Rogers-Ramachandran, 1996). Phantom limb patients position their other limb so that it's reflected in exactly the position that the amputated limb would assume. Then the patient performs the "mirror equivalent" of the exercise the amputated limb needs to relieve a cramp or otherwise get comfortable. For the mirror box to relieve pain or discomfort in the amputated limb, the illusion must be realistic. Seventeen out of 18 patients were successfully treated for phantom limb pain with the mirror box following amputation of one or more lower limbs resulting from injuries suffered as a result of the 2010 earthquake in Haiti (Miller et al., 2012).

The mirror box consists of a two-chamber box with a mirror in the center. When the participant looks at her right hand in the box, it creates the illusion that the mirror image of her right hand is her left hand. This box can sometimes alleviate the discomfort of phantom limb pain by positioning the intact limb as the phantom limb appears to be positioned, and then moving it to a more comfortable position.

phantom pain
pain or discomfort felt in an amputated limb

proprioception
our sense of body position

psychomythology

PSYCHIC HEALING OF CHRONIC PAIN

Many people believe in the power of mind over pain, but some individuals claim to possess supernatural abilities or "gifts" that enable them to reduce others' pain. Is this fact or fiction? In the summer of 2003, the Australian television show *A Current Affair* approached psychologists at the University of Bond to conduct a double-blind, randomized, controlled test of psychic healing powers.

Using a newspaper advertisement, the researchers located volunteers suffering from pain caused by cancer, chronic back conditions, and fibromyalgia (a chronic condition of muscle, joint, and bone pain and fatigue) (Lyvers, Barling, & Harding-Clark, 2006). The researchers assigned half of the chronic pain participants to a group that received psychic healing and the other half to a control condition that didn't. Neither the participants nor those interacting with them knew who was assigned to which group. In the healing condition, the psychic healer viewed and touched photographs of the chronic pain participants in another room. The healer was given all the time deemed necessary.

The researchers used the McGill Pain Questionnaire (Melzack, 1975) to test chronic pain participants' level of discomfort before and after the trial. Then, researchers compared their before and after scores. On average the scores showed no change before and after treatment, with half the participants reporting more pain and half reporting less pain regardless of whether psychic healing occurred.

These results agreed with earlier results obtained by British researchers on spiritual healing (Abbot et al., 2001). In a study of 120 chronic pain sufferers, they similarly used the McGill Pain Questionnaire. These researchers compared pain reports before and after face-to-face versus distant spiritual healing compared with no spiritual healing. The results suggested that despite the popularity of spiritual healing in England, this method lacks scientific support. A different research team, however, reported an improvement in neck pain following spiritual healing (Gerard, Smith, & Simpson, 2003). But because their study lacked a placebo treatment or blinding of the therapist, these authors couldn't rule out a placebo effect (see Chapter 2).

Lyvers and colleagues (2006) addressed the placebo effect with a double-blind design, and rated their chronic pain participants on a five-point scale that assessed the degree to which they believed in psychic phenomena. They found no correlation between psychic healing and decreased pain; however, they found that decreases in reported pain correlated with increased belief in psychic phenomena. So beliefs in the paranormal may create reality, at least psychological reality.

RULING OUT RIVAL HYPOTHESES
Have important alternative explanations for the findings been excluded?

WHEN WE CAN'T FEEL PAIN. Just as some people are blind or deaf, others experience disorders that impair their ability to sense pain. Although pain isn't fun, research on pain insensitivity shows that pain serves an essential function. Pain insensitivity present from birth is an extremely rare condition that is sometimes inherited (Victor & Ropper, 2001). For the most part, children with this condition are completely unable to detect painful stimuli. Lacking any awareness of pain, they may chew off parts of their bodies, like their fingertips or the ends of their tongues, or suffer bone fractures without realizing it. Needless to say, this condition can be exceedingly dangerous. Other individuals show an indifference to painful stimuli: They can identify the type of pain, but experience no significant discomfort from it.

Ashlyn Blocker has congenital insensitivity to pain with anhidrosis (CIPA). *Congenital* means "present at birth," and *anhidrosis* means "inability to sweat." CIPA is a rare disorder that renders people unable to detect pain or temperature; those affected also can't regulate body temperature well because of an inability to sweat. Her parents and teachers need to monitor her constantly because she's prone to eating scalding hot food without the slightest hesitation. She may badly injure herself on the playground and continue to play.

Proprioception and Vestibular Sense: Body Position and Balance

Right at this moment you're probably sitting somewhere. You may not be thinking about body control or keeping your head and shoulders up, because your brain is kindly taking care of all that for you. If you decided to stand up and grab a snack, you'd need to maintain posture and balance, as well as navigate bodily motion. **Proprioception**, also called our *kinesthetic sense*, helps us keep track of where we are and move efficiently. The **vestibular sense**, also called our *sense of equilibrium*, enables us to sense and maintain our balance as we move about. Our senses of body position and balance work together.

PROPRIOCEPTORS: TELLING THE INSIDE STORY. We use *proprioceptors* to sense muscle stretch and force. From these two sources of information we can tell what our bodies are doing, even with our eyes closed. There are two kinds of proprioceptors: stretch receptors embedded in our muscles, and force detectors embedded in our muscle tendons. Proprioceptive information enters the spinal cord and travels upward through the brain stem and thalamus to reach the somatosensory and motor cortexes (Naito, 2004). There, our brains combine information from our muscles and tendons, along with a sense of our intentions, to obtain a perception of our body's location (Proske, 2006).

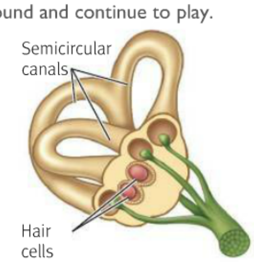


FIGURE 4.22 How We Sense Motion. The semicircular canals of the inner ear detect movement and gravity.

THE VESTIBULAR SENSE: A BALANCING ACT. In addition to the cochlea, the inner ear contains three **semicircular canals** (see **FIGURE 4.22**). These canals, which are filled with fluid, sense equilibrium and help us maintain our balance. Vestibular information reaches parts of the brain stem that control eye muscles and triggers reflexes that coordinate eye and head movements (Highstein, Fay, & Popper, 2004). Vestibular information also travels to the cerebellum, which controls bodily responses that enable us to catch our balance when we're falling.

vestibular sense
our sense of equilibrium or balance

semicircular canals
three fluid-filled canals in the inner ear responsible for our sense of balance

The vestibular sense isn't heavily represented in our cerebral cortex, so our awareness of this sense is limited. We typically become aware of this sense only when we lose our sense of balance or experience dramatic mismatches between our vestibular and visual inputs, which occur when our vestibular system and our eyes tell us different things. We commonly experience dizziness and nausea following these mismatches, such as when we're moving quickly in a car while not looking outside at the road whizzing past us.

Ergonomics: Human Engineering

How do our bodies interact with new technologies? A field of psychology called *human factors* optimizes technology to better suit our sensory and perceptual capabilities. We can use what we know about human psychology and sensory systems—ranging from our body position sense to vision—to build more *ergonomic,* or worker-friendly, gadgets and tools of the trade.

As Donald Norman (1998) pointed out, many everyday objects are designed without the perceptual experiences of users in mind. As a result, they can be extremely difficult to figure out how to operate. Have you ever tried to repeatedly push open a door that needed to be pulled open, or spent several minutes trying to figure out how to turn on a shower in an apartment or hotel room? Poor design kept the United States in limbo for five weeks following the 2000 presidential election between George W. Bush and Al Gore, when a bewildering election ballot in some Florida counties left state officials unable to figure out which candidate voters picked.

? Psychologist Donald Norman, posing in his office behind a teapot. Can you figure out what makes this teapot design a poor one? (See answer upside down on bottom of page.)

Fortunately, human factors psychologists have applied their extensive knowledge of sensation and perception to improve the design of many everyday devices. To take just one example, many people hold jobs that require them to sit at a computer terminal most of the day. This means that a new design for a computer screen, keyboard, or mouse that enables them to better reach for their computers or see their screens can increase their efficiency. Human factors psychologists design not only computer components, but devices that assist surgeons in performing delicate operations, workstations to improve comfort and decrease injuries on the job, and control panels on aircraft carriers, to make them safer and easier to use. The psychology of human factors reminds us that much of what we know about sensation and perception has useful applications to many domains of everyday life.

Study and **Review** in **MyPsychLab**

Assess Your Knowledge — FACT or FICTION?

1. Pain information travels more quickly to the spinal cord than does touch information. **True / False**
2. Pain thresholds vary depending on the person and type of pain (stabbing, burning, or aching, for example). **True / False**
3. Firewalking requires both insensitivity to pain and extremely high levels of motivation. **True / False**
4. Proprioception enables us to coordinate our movements without having to look at our bodies. **True / False**
5. The inner ear plays a key role in our ability to keep our balance. **True / False**

Answers: 1. F (p. 146); 2. T (p. 147); 3. F (p. 148); 4. T (p. 148); 5. T (p. 149)

Answer: The handle is directly underneath the spout, which would cause hot tea to pour directly onto your hand.

Perception: When Our Senses Meet Our Brains

4.12 Track how our minds build up perceptions.

4.13 Describe how we perceive people, objects, and sounds in our environment.

4.14 Distinguish subliminal perception from subliminal persuasion.

4.15 Analyze the scientific evidence for and against the existence of ESP.

Now that we've learned how we process sensory information, we'll embark on an exciting voyage into how our minds organize the bits of sensory data into more meaningful concepts. What's so remarkable about our brain's ability to bring together so much data is that it doesn't rely only on what's in our sensory field. Our brain pieces together (a) what's in the sensory field, along with (b) what was just there a moment ago, and (c) what we remember from our past. When we perceive the world, we sacrifice small details in favor of crisp and often more meaningful representations. In most cases, the trade-off is well worth it, because it helps us make sense of our surroundings.

FIGURE 4.23 What Do You See? Due to the influence of top-down processing, reading the caption "saxophone player" beneath this ambiguous figure tends to produce a different perception than reading the caption "woman."

FIGURE 4.24 Context Influences Perception. Depending on the perceptual set provided by the context of the surrounding letters, the middle letter can appear as an "H" or as an "A." Most of us read this phrase as "THE BAT" because of the context.

FIGURE 4.25 An Example of Perceptual Set. Depending on our perspective, the drawing on top can appear to be a young woman or an old one. Which did you perceive first? Look at the biased pictures (turn the page upside down) to alter your perceptual set. (*Source:* Hill, 1915)

Parallel Processing: The Way Our Brain Multitasks

We can attend to many sense modalities simultaneously, a phenomenon called **parallel processing** (Rumelhart & McClelland, 1987). Two important concepts that go along with parallel processing are **bottom-up processing** and **top-down processing** (see Chapter 8). In bottom-up processing, we construct a whole stimulus from its parts. An example is perceiving an object on the basis of its edges. Bottom-up processing starts with the raw stimuli we perceive and ends with our synthesizing them into a meaningful concept. This kind of processing begins with activity in the primary visual cortex, followed by processing in the association cortex (see Chapter 3). In contrast, top-down processing starts with our beliefs and expectations, which we then impose on the raw stimuli we perceive. Top-down processing starts with processing in the association cortex, followed by processing in the primary visual cortex.

Some perceptions rely more heavily on bottom-up processing (Koch, 1993), others on top-down processing (McClelland & Plaut, 1993). In most cases, though, these two kinds of processing work hand in hand (Patel & Sathian, 2000). We can illustrate this point by how we process ambiguous figures (see **FIGURE 4.23**). Depending on our expectations, we typically perceive these figures differently. The top-down influence that we're thinking of a jazz musician biases our bottom-up processing of the shapes in Figure 4.23 and increases the chances we'll perceive a saxophone player. In contrast, if our top-down expectation were of a woman's face, our sensory-based bottom-up processing would change accordingly. Can you see both figures?

Perceptual Hypotheses: Guessing What's Out There

Because our brains rely so much on our knowledge and experiences, we can usually get away with economizing in our sensory processing and making educated guesses about what sensory information is telling us. Moreover, a pretty decent guess with fewer neurons is more efficient than a more certain answer with a huge number of neurons. As cognitive misers, we generally try to get by with as little neural firepower as we can (see Chapter 2).

PERCEPTUAL SETS. We form a **perceptual set** when our expectations influence our perceptions—an example of top-down processing. We may perceive a misshapen letter as an "H" or as an "A" depending on the surrounding letters and the words that would result from our interpretation (see **FIGURE 4.24**). We also tend to perceive the world in accord with our preconceptions. An ambiguous cartoon drawn by W. E. Hill raises the question: Is it a young woman or an old witch? Participants placed in the perceptual set of a young woman by viewing a version of the cartoon exaggerating those features (see **FIGURE 4.25**)

parallel processing
the ability to attend to many sense modalities simultaneously

bottom-up processing
processing in which a whole is constructed from parts

top-down processing
conceptually driven processing influenced by beliefs and expectancies

perceptual set
set formed when expectations influence perceptions

reported seeing a young woman. In contrast, participants placed in the perceptual set of an old woman by viewing a version of the cartoon exaggerating those features reported seeing an old woman (Boring, 1930).

PERCEPTUAL CONSTANCY. The process by which we perceive stimuli consistently across varied conditions is **perceptual constancy**. Without perceptual constancy, we'd be hopelessly confused, because we'd be seeing our worlds as continually changing. Yet our brain allows us to correct from these minor changes. There are several kinds of perceptual constancy: shape, size, and color constancy. Consider a door we view from differing perspectives (see **FIGURE 4.26**). Because of *shape constancy,* we still see a door as a door whether it's completely shut, barely open, or more fully open, even though these shapes look almost nothing like each other.

FIGURE 4.26 Shape Constancy. We perceive a door as a door whether it appears as a rectangle or a trapezoid.

Or take *size constancy,* our ability to perceive objects as the same size no matter how far away they are from us. When a friend walks away from us, her image becomes smaller. But we almost never realize this is happening, nor do we conclude that our friend is mysteriously shrinking. Outside of our conscious awareness, our brains mentally enlarge figures far away from us so that they appear more like similar objects in the same scene.

The man standing toward the back of the bridge looks to be of normal size, but the exact duplicate image appears in the foreground and looks like a toy because of size constancy.

Color constancy is our ability to perceive color consistently across different levels of lighting. Consider a group of fire fighters dressed in bright yellow jackets. Their jackets look bright yellow even in very low levels of light. That's because we evaluate the color of an object in the context of background light and surrounding colors. Take a moment to examine **FIGURE 4.27**. The checkerboard appears to contain all black and white squares, but they're actually varying shades of gray. Remarkably, the A and B squares (one from the black set and one from the white set) are exactly the same shade of gray. Dale Purves and colleagues (2002) applied the same principle to cubes composed of smaller squares that appear to be of different colors, even though some of the smaller squares are actually gray (see **FIGURE 4.28**). We base our perception of color in these smaller squares on the surrounding context.

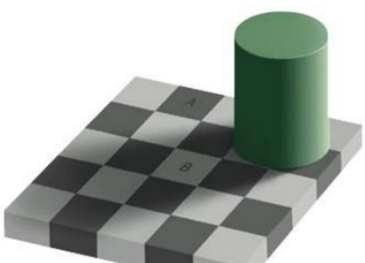


FIGURE 4.27 The Checker-Shadow Illusion. We perceive a checkerboard pattern of black and white alternating squares, and because of color constancy, we ignore the dramatic change due to the shadow cast by the green cylinder. Believe it or not, the A and B squares are identical. (*Source:* © 1995 Edward H. Adelson)

GESTALT PRINCIPLES. As we have learned, much of our visual perception involves analyzing an image in the context of its surroundings and our expectations. Our brains often provide missing information about outlines, a phenomenon called *subjective contours.* Gaetano Kanizsa sparked interest in this phenomenon in 1955. His figures illustrate how a mere hint of three or four corners can give rise to the perception of an imaginary shape (see **FIGURE 4.29**).

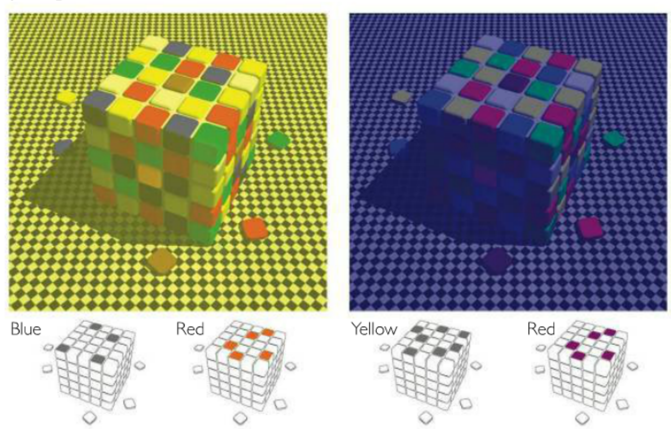


FIGURE 4.28 Color Perception Depends on Context. Gray can appear like a color depending on surrounding colors. The blue-colored squares on the top of the cube at the left are actually gray (*see map below the cube*). Similarly, the yellow-colored squares on the top of the cube at the right are actually gray (*see map below the cube*). (*Source:* © Dale Purves and R. Beau Lotto, 2002)

perceptual constancy
the process by which we perceive stimuli consistently across varied conditions

Gestalt principles are rules governing how we perceive objects as wholes within their overall context (*Gestalt* is a German word roughly meaning "whole"). Gestalt principles of perception help to explain why we see much of our world as consisting of unified figures or forms rather than confusing jumbles of lines and curves. These principles provide a road map for how we make sense of our perceptual worlds.

Here are the main Gestalt principles, formulated by psychologists Max Wertheimer, Wolfgang Kohler, and Kurt Koffka in the early 20th century (see **FIGURE 4.30**):

Simulate in **MyPsychLab** the **Experiment:** Gestalt Laws of Perception

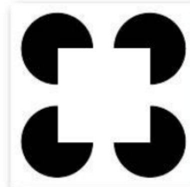


FIGURE 4.29 Kanizsa Square. This Kanizsa square illustrates subjective contours. The square you perceive in the middle of this figure is imaginary.

1. **Proximity:** Objects physically close to each other tend to be perceived as unified wholes (Figure 4.30a).
2. **Similarity:** All things being equal, we see similar objects as comprising a whole, much more so than dissimilar objects. If patterns of red circles and yellow circles are randomly mixed, we perceive nothing special. But if the red and yellow circles are lined up horizontally, we perceive separate rows of circles (Figure 4.30b).
3. **Continuity:** We still perceive objects as wholes, even if other objects block part of them. The Gestalt principle of continuity leads us to perceive the cross shown in Figure 4.30c as one long vertical line crossing over one long horizontal line rather than four smaller line segments joining together.
4. **Closure:** When partial visual information is present, our brains fill in what's missing. When the missing information is a contour, this principle is essentially the same as subjective contours. This Gestalt principle is the main illusion in the Kanizsa figures (Figure 4.30d).
5. **Symmetry:** We perceive objects that are symmetrically arranged as wholes more often than those that aren't. Figure 4.30e demonstrates that two symmetrical figures tend to be grouped together as a single unit.
6. **Figure–ground:** Perceptually, we make an instantaneous decision to focus attention on what we believe to be the central figure, and largely ignore what we believe to be the background. We can view some figures, such as Rubin's vase illusion, in two ways (Figure 4.30f). The vase can be the figure, in which case we ignore the background. If we look again, we can see an image in the background: two faces looking at each other.

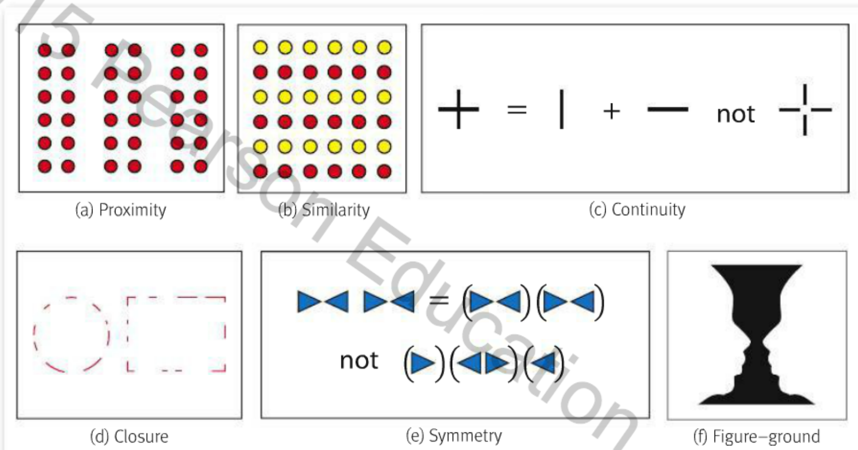


FIGURE 4.30 Gestalt Principles of Perception. As Gestalt psychologists discovered, we use a variety of principles to help us organize the world.

Rubin's vase illusion is an example of a *bistable* image, one we can perceive in two ways. Another example is the Necker Cube in **FIGURE 4.31**. When we look at bistable images, we can typically perceive them only one way at a time, and there are limits to how quickly we can shift from one view to the other. A concept related to the bistable image is *emergence*—a perceptual gestalt that almost jumps out from the page and hits us all at once. Try to find the Dalmatian dog in the image on the next page. If you have trouble, keep staring at the black-and-white image until the dog emerges. It's worth the wait.

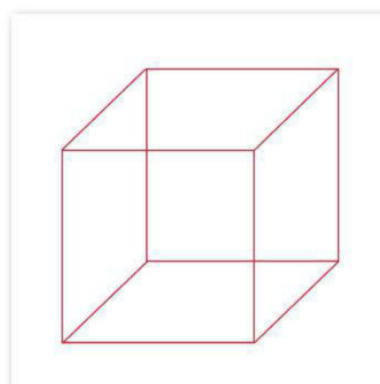


FIGURE 4.31 The Necker Cube. The Necker cube is an example of a bistable image.

HOW WE PERCEIVE FACES. Our ability to recognize familiar faces, including our own, lies at the core of our social selves. After all, don't we refer to a friend as "a familiar face"? Even nonhuman primates can recognize faces (Pinsk et al., 2005).

Watch in **MyPsychLab** the **Video:** Special Topics: Recognizing Faces

Embedded in this photograph is an image of a Dalmatian dog. Can you find it?

We don't need an exact picture of a face to recognize it. Caricature artists have long capitalized on this fact and amused us with their drawings of famous faces, usually with some feature exaggerated way out of proportion. Yet we can recognize wacky faces because our brains get by with only partial information, filling in the rest for us. Do individual neurons respond specifically to certain faces? Scientists have known for some time that the lower part of the temporal lobe responds to faces (refer back to Figure 4.10). Researchers have identified neurons in the human hippocampus that fire selectively in response to celebrity faces, such as those of Jennifer Aniston and Halle Berry (Quiroga et al., 2005) (see Chapter 7). In the 1960s, Jerry Lettvin half-jokingly proposed that each neuron might store a single memory, like the recollection of our grandmother sitting in our living room when we were children. He coined the term "grandmother cell" to describe this argument, assuming it could be easily falsified (Horgan, 2005).

FALSIFIABILITY Can the claim be disproved?

Certain neurons, such as those responding to Jennifer Aniston, are suggestive of grandmother cells, but we shouldn't be too quick to accept this possibility. Even though individual cells may respond to Aniston, many other neurons in other brain regions probably chime in, too. Researchers can only make recordings from a small number of neurons at once, so we don't know what the rest of the brain is doing. At present, the most parsimonious hypothesis is that sprawling networks of neurons, rather than single cells, are responsible for face recognition.

OCCAM'S RAZOR Does a simpler explanation fit the data just as well?

HOW WE PERCEIVE MOTION. The brain judges how things in our world are constantly changing by comparing visual frames, like those in a movie. Perceiving the motion of a car coming toward us as we cross the street relies on this kind of motion detection, and we couldn't cross the street, let alone drive a car, without it. We can also be fooled into seeing motion when it's not there. Moving closer to and farther from certain clever designs produces the illusion of motion, as we can see in **FIGURE 4.32**. The *phi phenomenon,* discovered by Max Wertheimer, is the illusory perception of movement produced by the successive flashing of images, like the flashing lights that seem to circle around a movie marquee. These lights are actually jumping from one spot on the marquee to another, but they appear continuous. The phi phenomenon shows that our perceptions of what's moving and what's not are based on only partial information, with our brains taking their best guesses about what's missing. Luckily, many of these guesses are accurate, or at least accurate enough for us to get along in everyday life.

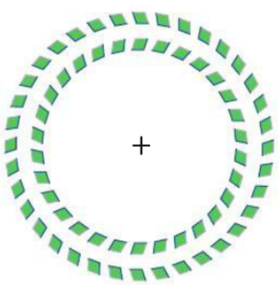


FIGURE 4.32 Moving Spiral Illusion. Focus on the plus sign in the middle of the figure and move the page closer to your face and then farther away. The two rings should appear to move in opposite directions, and those directions should reverse when you reverse the direction in which you move the page.

Motion blindness is a serious disorder in which patients can't seamlessly string still images processed by their brains into the perception of ongoing motion. As we noted earlier, motion perception is much like creating a movie in our heads. Actual movies contain 24 frames of still photos per second, creating the illusory perception of motion. In patients with motion blindness, many of these "frames" are missing. This disability interferes with many simple tasks, like crossing the street. Imagine a car appearing to be 100 feet away and then suddenly jumping to only one foot away a second or two later. Needless to say, the experience would be terrifying. Life indoors isn't much better. Simply pouring a cup of coffee can be enormously challenging, because the person doesn't see the cup fill up. First, it's empty and then is overflowing with coffee onto the floor only a moment later.

HOW WE PERCEIVE DEPTH. **Depth perception** is the ability to see spatial relations in three dimensions; it enables us to reach for a glass and grasp it rather than knock it over and spill its contents. We need to have some idea of how close or far we are from objects to navigate around our environments. We use two kinds of cues to gauge depth: **monocular depth cues**, which rely on one eye alone, and **binocular depth cues**, which require both eyes.

depth perception
ability to judge distance and three-dimensional relations

monocular depth cues
stimuli that enable us to judge depth using only one eye

binocular depth cues
stimuli that enable us to judge depth using both eyes

Monocular Cues. We can perceive three dimensions using only one eye. We do so by relying on *pictorial cues* to give us a sense of what's located where in stationary scenes. The following pictorial cues help us to perceive depth.

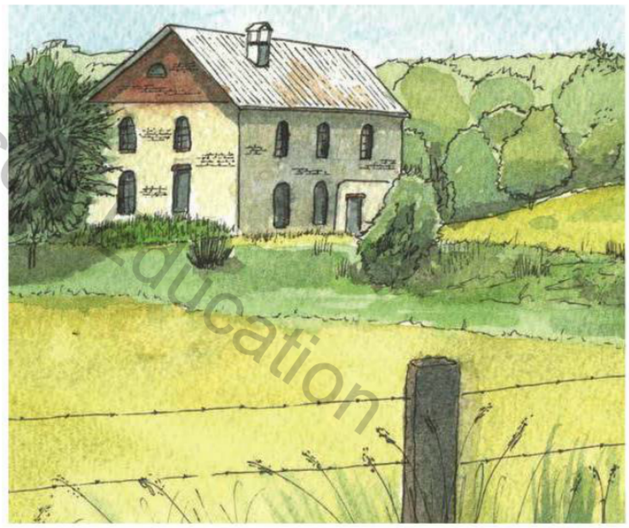
- **Relative size:** All things being equal, more distant objects look smaller than closer objects.
- **Texture gradient:** The texture of objects becomes less apparent as objects move farther away.
- **Interposition:** One object that's closer blocks our view of an object behind it. From this fact, we know which object is closer and which is farther away.
- **Linear perspective:** The outlines of rooms or buildings converge as distance increases, a fact exploited by artists. We can trace most lines in a scene to a point where they meet—the *vanishing point*. In reality, lines in parallel never meet, but they appear to do so at great distances. Some *impossible figures*—figures that break physical laws—possess more than one vanishing point. Artist M. C. Escher was fond of violating this rule in his prints.
- **Height in plane:** In a scene, distant objects tend to appear higher, and nearer objects lower.
- **Light and shadow:** Objects cast shadows that give us a sense of their three-dimensional form.

One additional monocular cue that's not pictorial is *motion parallax:* the ability to judge the distance of moving objects from their speed. Nearby objects seem to move faster than those far away traveling at the same speed. Motion parallax also works when we're moving. Stationary objects nearer to us pass us more quickly than objects farther away, a fact we'll discover when looking out of the windows of a moving car. Our brains quickly compute these differences in speed and calculate approximate distances from us.

Binocular Cues. Our visual system is set up so that we view each of our two visual fields with both eyes. We'll recall that half of the axons in the optic nerve cross to the other side and half stay on the same side before entering the brain. Visual information from both sides is sent to neighboring cells in the visual cortex, where our brains can make comparisons. These comparisons form the basis of binocular depth perception; we use several binocular cues to perceive depth in our worlds.

- **Binocular disparity:** Like the two lenses from a pair of binoculars, our left and right eyes transmit quite different information for near objects but see distant objects similarly. To demonstrate this cue, close one of your eyes and hold a pen up about a foot away from your face, lining the top of it up with a distant point on the wall (like a doorknob or corner of a picture frame). Then, hold the pen steady while alternating which of your eyes is open. You'll find that although the pen is lined up with one eye, it's no longer lined up when you switch to the other eye. Each eye sees the world a bit differently, and our brains ingeniously make use of this information to judge depth.

Gisela Leibold is unable to detect motion. She's understandably concerned about important information she might miss riding down an escalator in Munich.



This painting depicts a scene that provides monocular cues to depth.

1. Relative size: The house is drawn approximately as high as the fence post, but we know the house is much bigger, so it must be considerably farther away.
2. Texture gradient: The grasses in front of the fence are drawn as individual blades but those in the field behind are shown with almost no detail.
3. Interposition: The tree at the corner of the house is blocking part of the house, so we know that the tree is closer to us than the house is.

This lithograph by M. C. Escher titled *Belvedere* (1958) features two vanishing points, resulting in an impossible structure. Can you locate the vanishing points off the page?