Chapter 3 *Sensation and Perception*

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I. OUR SENSATIONAL SENSES

- *Lecture Launcher 3.1 - Setting Thresholds*
- *Lecture Launcher 3.2 - The Sensory System*

- *Activity 3.1 - Pressure Phosphene*
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- *REVEL Multimedia*
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Learning Objective 3.1.A - Distinguish between sensation and perception, and explain how the doctrine of specific nerve energies and synesthesia contribute to our understanding of sensory modalities.

A. Definitions
  1. Sensation--the detection of physical energy emitted or reflected by physical objects
  2. Perception--processes that organize sensory impulses into meaningful patterns
  3. Introduction to the senses
     a. There are five widely known senses and other lesser known senses
     b. All senses evolved to help us survive

B. The riddle of separate sensations
  1. Sense receptors stimulate sensory neurons which stimulate brain cells
  2. Encoding the electrical messages--the nervous system uses two kinds of codes
     a. Anatomical codes
        (1) Doctrine of specific nerve energies--signals received by the sense organs stimulate different nerve pathways, which terminate in different areas of the brain
        (2) Does not fully explain separate sensations; different skin senses do not have distinct nerve pathways; different colors do not have distinct pathways
     b. Functional codes
        (1) Particular receptors fire or are inhibited in the presence of certain stimuli
        (2) Codes relate to which cells, how many, and the rate and pattern of firing
  3. Synesthesia occurs when stimulation of one sense evokes sensations in another

Learning Objective 3.1.B - Differentiate between absolute thresholds, difference thresholds, and signal detection.

C. Measuring the senses
  1. Psychophysics--how the physical properties of stimuli are related to our psychological experience of them
  2. *Absolute threshold*--the smallest amount of energy a person can detect reliably (50 percent of the time)
  3. *Difference threshold*--the smallest difference in stimulation that a person can detect reliably (50 percent of the time); also called just noticeable difference (jnd)
  4. *Signal detection theory*
     a. Accounts for response bias (tendency to say yes or no to a signal)
     b. Separates sensory processes (the intensity of the stimulus) from the decision process (influenced by observer's response bias)

Learning Objective 3.1.C - Discuss why the principle of sensory adaptation helps us understand how the human perceptual system works.

D. Sensory adaptation
   1. Decline in sensory responsiveness occurs when a stimulus is unchanging; nerve cells temporarily stop responding
   2. Sensory deprivation studies
      a. Early deprivation study subjects became edgy, disoriented, confused, restless and had hallucinations
      b. Early studies exaggerated negative reactions
   3. Brain requires minimum stimulation to function normally

Learning Objective 3.1.D - Describe how selective attention and inattentional blindness are related.

E. Sensing without perceiving
   1. Selective attention protects us from being overwhelmed with sensations
   2. Inattentional blindness can keep us from seeing what's right before our very eyes

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II. VISION

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- *Activity 3.11 - Using Escher to Illustrate Perceptual Principles*
- *Activity 3.12 - Rods and Cones*

- *REVEL Multimedia*
- *MyPsychLab Multimedia*

Learning Objective 3.2.A - Describe the three psychological dimensions of vision and the three physical properties of light that produce them.

A. What we see
   1. Stimulus for vision is light, which travels in waves
   2. Characteristics of light waves
      a. Hue--color that is related to wavelength
      b. Brightness--intensity, corresponds to amplitude of the wave
      c. Saturation--colorfulness--complexity of the range of wavelengths
   3. Psychological dimensions of visual experience--hue, brightness, saturation
   4. Physical properties of light--wavelength, intensity, complexity

Learning Objective 3.2.B - Locate the structures and cells of the human eye, tracing the path that light follows from the cornea to the optic nerve.

B. An eye on the world
   1. Cornea--front part of the eye; protects the eye and bends light rays toward lens
   2. Lens--located behind the cornea; focuses light by changing curvature
   3. Iris--muscles that control the amount of light that gets into the eye
   4. Pupil--round opening surrounded by iris; widens and dilates to let light in
   5. Retina--located in the back of the eye, contains visual receptors

a. Parts of retina
   (1) Two types of receptors
      (a) Rods: sensitive to light, not to color
      (b) Cones: see color, but need more light to respond
   (2) Fovea--center of retina, sharpest vision, contains only cones
b. Processing visual information
   (1) Dark adaptation--time it takes to adjust to dim illumination--reflects mainly increase in sensitivity of rods
   (2) Rods and cones connect to bipolar neurons that connect to ganglion cells, whose axons converge to form optic nerve, that carries information out of the eye to the brain
   (3) Optic nerve--leaves the eye at optic disc--no rods or cones--blind spot on retina

Learning Objective 3.2.C - Summarize the evidence indicating that the visual system is not simply a "camera."

C. Why the visual system is not a camera
   1. Eyes are not a passive recorder of external world; neurons build picture of the external world by detecting its meaningful features
   2. Special feature detector cells in visual cortex code complex features
   3. Other cells in the visual system respond maximally to certain specific visual information like faces, bull's-eyes, or starlike shapes
   4. Frequency, pattern, and rhythm of firing all provide information to the brain

Learning Objective 3.2.D - Compare the trichromatic and opponent-process theories of color vision.

D. How we see colors
   1. Trichromatic (Young-Helmholtz) theory
      a. This approach applies to the first level of processing (in the retina)
      b. Retina contains three types of cones: one responds to blue, another to green,another to red; these combine to make all colors
      c. People with color deficiencies lack particular types of cones
   2. Opponent-process theory
      a. Second stage of color processing in the ganglion cells of the retina and neurons in the thalamus and visual cortex (opponent process cells)
      b. They turn off to one wavelength in a pair and on to the other
      c. Another opponent-process system responds in opposing fashion to black and white, providing information about brightness
      d. Opponent-process theory can explain why we see negative afterimages
   3. Perceived color of an object also depends on the wavelengths reflected by the other objects around it

Learning Objective 3.2.E - Summarize the principles and processes that guide form perception, depth and distance perception, visual constancies, and visual illusions.

E. Constructing the visual world
   1. Visual perception--the mind interprets the retinal image and constructs the world using information from other senses
   2. Form perception
      a. Gestalt psychologists studied how people organize the visual world into meaningful patterns
      b. Strategies for building perceptual units include use of: figure/ground distinction, proximity, closure, similarity, and continuity
   3. Depth and distance perception--object's location inferred from distance or depth cues
      a. Binocular cues--dependent on information from both eyes
         (1) Changes in angle of convergence of the image seen by each eye provide distance

cues
(2) Retinal disparity--disparity in the lateral separation between two objects as seen by the two eyes is used to infer depth or distance
b. Monocular cues--cues that do not depend on using both eyes include interposition and linear perspective
4. Visual constancies: When seeing is believing
a. Perceptual constancy--our perception of objects is unchanging though the sensory patterns they produce are constantly shifting
b. Visual constancies--shape, location, size, brightness, and color
5. Visual illusions: When seeing is misleading--visual constancies may occasionally fool us, resulting in visual illusions

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- *Lecture Launcher 3.10 - Perfect Pitch*
- *Lecture Launcher 3.11 - The Mosquito*
- *Lecture Launcher 3.12 - Is Your MP3 Player Hurting You?*
- *Lecture Launcher 3.13 - Hear, Here, and Over There*

- *Activity 3.13 - Auditory Localization*

- *REVEL Multimedia*
- *MyPsychLab Multimedia*

Learning Objective 3.3.A - Describe the three psychological dimensions of hearing and the three physical properties of sound that produce them.

A. What we hear
1. Stimulus for sound is a wave of pressure created when an object vibrates; that causes molecules in a transmitting substance (such as air) to move
2. Characteristics of sound waves
a. Loudness--intensity of a wave's pressure; corresponds to amplitude; also affected by pitch; units of measure are decibels
b. Pitch--frequency (and intensity) of wave; units of measure are hertz (cycles per second)
c. Timbre--complexity of wave; the distinguishing quality of a sound
3. When all frequencies of the sound spectrum are present, white noise occurs

Learning Objective 3.3.B - Locate the major structures of the human ear, and describe the functions of each component.

B. An ear on the world
1. Sound wave passes into the outer ear through a canal to strike the eardrum
2. Eardrum vibrates at the same frequency and amplitude as the wave
3. The wave vibrates three small bones in the inner ear--the hammer, anvil, and stirrups--intensify the sound; the third bone pushes on a membrane that guards the entrance to the inner ear, of which the cochlea is a part
4. The cochlea contains the receptor cells called cilia, or hair cells, that are embedded in the basilar membrane stretching across the cochlea
5. Pressure causes movement in the basilar membrane; the hair cells initiate a signal to the auditory nerve, which carries the message to the brain
6. The pattern of movement of the basilar membrane influences the pattern and frequency of how the neurons fire, which determines what is heard

Learning Objective 3.3.C - List and give examples of Gestalt principles of perception that apply to constructing the auditory world.

C. Constructing the auditory world
   1. Perception is used to organize patterns of sounds to construct meaning
   2. Strategies used to organize and interpret sounds include the Gestalt principles of figure/ground, proximity, continuity, similarity, closure
   3. Loudness is a distance cue
   4. Differences in loudness and/or time of arrival of auditory stimuli to the two ears allows us to estimate direction

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IV. OTHER SENSES

- *Lecture Launcher 3.14 - Sniffing Out the Truth About Fragrance*
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- *Activity 3.19 - Let Them Eat Jellybeans!*
- *Activity 3.20 - The Body's Sensitivity to Touch*

- *REVEL Multimedia*
- *MyPsychLab Multimedia*

Learning Objective 3.4.A - Identify the major structures of the human tongue, and list the five basic tastes perceived by humans.

A. Taste: savory sensations
   1. Chemicals stimulate receptors (inside taste buds) on tongue, throat, and roof of mouth
      a. Papillae--bumps on tongue, contain taste buds
      b. Taste receptors are replaced every 10 days--number of taste buds and receptor cells declines with age
   2. Four basic tastes: salty, sour, bitter, sweet
      a. Each taste produced by a different type of chemical
      b. Each can be perceived wherever there are receptors
      c. Flavors are a combination of the four, but unclear how this occurs
      d. Natural tastes--preference for sweet
      e. Taste influenced by smell, culture, individual differences, temperature, texture
      f. There are genetic differences in sensitivity to certain tastes
      g. *Umami* adds a fifth taste option

Learning Objective 3.4.B - Describe the basic pathway from smell receptors to the cerebral cortex.

B. Smell: The sense of scents
   1. The sense of smell is called olfaction
   2. Receptors are millions of specialized neurons embedded in a mucous membrane in upper part of nasal passage; respond to chemical molecules in the air
   3. Signals travel from receptors to olfactory bulb in the brain
   4. Not well understood--no agreement on which smells are basic; there may be a thousand different receptor types
   5. Sense of smell allows us to sniff out danger--smoke, spoiled food, poison gases
   6. Odor preferences influenced by culture, context, and experience
   7. Odors can prime thoughts and behavior

Learning Objective 3.4.C - List the four basic skin senses that humans perceive.

C. Senses of the skin
   1. Skin protects innards, helps identify objects, involved in intimacy, serves as boundary
   2. Skin senses include: touch (pressure), warmth, cold, and pain
      a. No correspondence between four sensations and types of receptors, except for pressure
      b. Many aspects of touch continue to baffle scientists

Learning Objective 3.4.D - Describe the principles of gate-control theory, and explain what phantom pain is and a novel way to treat it.

D. The mystery of pain
   1. Pain differs from the other skin senses in that removal of stimulus doesn't always terminate sensation
   2. Chronic pain puts stress on the body
   3. Gate-control theory of pain
      a. To experience pain sensation, impulses must pass a "gate" to central nervous system
      b. The gate is made of neurons that either transmit or block pain message
      c. Chronic pain results when fibers that close the gate are damaged
   4. The neuromatrix theory of pain
      a. Gate-control theory can't explain phantom pain
         (1) The brain can generate pain without external stimulation
         (2) The neuromatrix gives us a sense of our own bodies
         (3) Abnormal activity can occur in the neuromatrix as a result of memories and expectations

Learning Objective 3.4.E - Discuss the two senses that allow us to monitor our internal environment.

E. The environment within
   1. Kinesthesis--tells us about location and movement of body parts using pain and pressure receptors in muscles, joints, and tendons
   2. Equilibrium--gives information about position and motion of the body as a whole using three semicircular canals in the inner ear

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▼Learning Objectives

LO 3.1.A - Distinguish between sensation and perception, and explain how the doctrine of specific nerve energies and synesthesia contribute to our understanding of sensory modalities.

LO 3.1.B - Differentiate between absolute thresholds, difference thresholds, and signal detection.

LO 3.1.C - Discuss why the principle of sensory adaptation helps us understand how the human perceptual system works.

LO 3.1.D - Describe how selective attention and inattentional blindness are related.

LO 3.2.A - Describe the three psychological dimensions of vision and the three physical properties of light that produce them.

LO 3.2.B - Locate the structures and cells of the human eye, tracing the path that light follows from the cornea to the optic nerve.

LO 3.2.C - Summarize the evidence indicating that the visual system is not simply a "camera."

LO 3.2.D - Compare the trichromatic and opponent-process theories of color vision.

LO 3.2.E - Summarize the principles and processes that guide form perception, depth and distance perception, visual constancies, and visual illusions.

LO 3.3.A - Describe the three psychological dimensions of hearing and the three physical properties of sound that produce them.

LO 3.3.B - Locate the major structures of the human ear, and describe the functions of each component.

LO 3.3.C - List and give examples of Gestalt principles of perception that apply to constructing the auditory world.

LO 3.4.A - Identify the major structures of the human tongue, and list the five basic tastes perceived by humans.

LO3.4.B - Describe the basic pathway from smell receptors to the cerebral cortex.

LO3.4.C - List the four basic skin senses that humans perceive.

LO3.4.D - Describe the principles of gate-control theory, and explain what phantom pain is and a novel way to treat it.

LO3.4.E - Discuss the two senses that allow us to monitor our internal environment.

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►Rapid Review

Chapter 3 examines the processes of sensation and perception for the various senses, and the relationship between them. Receptors in the senses change physical energy into neural energy. The physical characteristics of the stimuli correspond to psychological dimensions of our sensory experience. Psychophysics (how the physical properties of stimuli are linked to psychological experiences), signal detection theory, sensory adaptation, and selective attention are discussed. After sensation has occurred, perception, the process of organizing and interpreting the sensory information, begins. The general processes of vision, hearing, taste, smell, pain, equilibrium, and kinesthesis are reviewed. For each of these senses, the chapter examines the relevant biological structures and processes (e.g., rods and cones) as well as the relevant theories that explain perception (e.g., trichromatic theory and opponent-process theory to explain how we see color). Perceptual strategies, including depth and distance strategies, visual constancies, and form perception, are described. The gate control theory of pain and a newer, modified version of the theory are reviewed.

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▼LECTURE LAUNCHERS AND DISCUSSION TOPICS

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Lecture Launcher 3.1 - Setting Thresholds

The methods for establishing thresholds have a long history to them, dating to the work of the original German psychophysicists:

■ *Method of limits*. The presentation of a stimulus that is clearly noticeable is followed by the presentation of increasingly weaker stimuli until observers are unable to detect the stimulus. For example, using the method of limits to establish an auditory threshold might involve presenting a clearly detectable tone, followed by tones of decreasing amplitude until the participant reports hearing no tone at all. This method then involves alternating trials of "no detection" with trials presenting increasingly stronger stimuli. In our example, after establishing the lowest level of detection, tones of increasing amplitude would be presented. These *descending* and *ascending series* of trials are typically repeated several times with one observer.

■ *Method of adjustment*. Observers control the intensity of stimulus until it is just barely noticeable. For example, the channel surfer who commandeers the remote control might turn the volume on the television set down until it is just barely audible. The distinguishing feature of this method is the self-adjustment by the perceiver.

■ *Method of constant stimuli.* This technique involves presenting a preselected set of stimuli in a random order to perceivers. The stimuli are chosen so that at least one is clearly below the sensory threshold (established previously, perhaps, by the method of adjustment) and at least one is clearly above the sensory threshold. In a hearing test, for example, a set of tones of varying amplitudes might be presented to a perceiver at random, and the perceiver's ability to discriminate among them would be measured.

Fechner, G. T. (1860). *The elements of psychophysics*. Leipzig: Breitkopf & Harterl.
Foley, H. J., & Matlin, M. W (2009). *Sensation and perception* (5th ed.). Upper Saddle River, NJ: Pearson.

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Lecture Launcher 3.2 - The Sensory System

Check this out. There are three different types of sensory systems, each of which performs different functions:

Exteroceptors. These sensory receptors collect data from the external world, and there are two types: distal and proximal receptors. Distal receptors include those associated with vision. Objects rarely make direct contact with the eye; rather they are discerned at a distance, with no need for contact in order to experience the sensation. Proximal receptors are associated with touch, taste, and possibly olfaction. In most instances, proximal systems require direct contact with the stimulus. Thermal radiation does not always require proximity; you can tell that the sun is warm via your distal receptors, without having to touch it.

Interoceptors. These are internal system monitors; they work to keep you aware of the internal workings of your body, such as letting you know when you are hungry, thirsty, in pain, nauseated, fatigued, and so on.

Proprioceptors. These receptors monitor the position of the body or limbs relative to some reference point. They let you know where you are physically located in space. Proprioceptors are found in the vestibular system (where they permit maintenance of your physical position), in the pressure receptors of the skin, in the muscle stretch receptors of your muscles, and in the joint movement receptors of your limbs.

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Lecture Launcher 3.3 - A Few Animal Facts

You can spice up a discussion of the anatomy of the eye by comparing the visual abilities of animals and humans. The senses of animals have evolved to give members of some species an optimum chance for survival. Here are a few examples:

Some animals, such as cats, have a reflective surface on the back of the eye behind the sensory receptors. When light first enters the eye, some light is detected by the sensory receptors. The light not detected by the sensory receptors continues onto the reflective surface at the back of the eye. This light is then reflected outward toward the sensory receptors, providing a second opportunity for detection. This feature produces two results. First, the outward reflection results in the shining of the cat's eye when a light beam falls onto it. The second result is that the cat's night vision efficiency is doubled over that of animals with a nonreflective rear surface, such as humans.

Diurnal animals, such as fish and birds, have all or mostly cones on their retinas. Their superior color vision is a strong advantage during daylight, but they are nearly blind at night. Nocturnal animals, such as rats and bats, have all or mostly rods on their retinas; therefore they have no color vision, but they can see at night. The retinas of humans contain both rods and cones; therefore humans can see things at night and with color during the day.

Most herbivores and prey animals have their eyes placed far to the side of the head to give them a wide range of vision, whereas carnivores, including humans, have their eyes closer together so the overlapping visual fields can provide good depth perception. This is easy to remember using the old saying, "Eyes wide, likes to hide; eyes front, likes to hunt."

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Lecture Launcher 3.4 - Visual Agnosia: The Case of P.T.

While in his thirties, patient P.T. had experienced a severe stroke that affected his left hemisphere; then, when in the hospital, he experienced another stroke that affected his right hemisphere. Although P.T. seemed to recover from some of the physical effects of the second stroke (e.g., dizziness, muscular weakness on the right side of his body), he still dragged his left leg slightly, but he was completely unaware of it.

Upon returning to his small family farm, he had difficulty readjusting to daily routines. Specifically, he had difficulty recognizing objects and places. He would work on his farm, then look across the landscape and not be able to recognize it. He could not discriminate among cows, which is necessary for choosing which cows to milk. Most noticeable was his inability to recognize faces, even that of his wife. Furthermore, he knew that another's arms, legs, head, and body went together as a person; however, he could not recognize who that person was. He could recognize that his wife moving across the room was still his wife, thus maintaining some perceptual constancies. Interestingly, only his visual perception was impaired; he could readily recognize the sound of his wife's voice, and he could identify objects by touch or smell. For example, when presented with a candle, he reported that it was a "long object." When he was allowed to hold the candle, he labeled it a crayon, and when he smelled it, he correctly recognized it as a candle.

Gazzaniga, M. S., Ivry, R. B., & Mangun, G. R. (2013). *Cognitive neuroscience: The biology of the mind.* (4th ed.). New York: W. W. Norton & Company.

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Lecture Launcher 3.5 - Hey Man…Light Show! Cool!

Most colors, including white, gray, and all the desaturated pastels, as well as the nonspectral colors, can be seen only when two or more different wavelengths are mixed. This raises the important question of how colors combine. The answer varies, depending on whether lights or paints are mixed; here we will discuss light mixture.

The result of mixing lights of two colors in color space will fall somewhere along a line drawn between them in the color spindle. If they are mixed in equal amounts, the result will be a color midway between them; if the mixture contains more of one than the other, the resulting color is correspondingly closer to the heavier contributor but nonetheless along the line connecting them.

One very important fact about light mixture is that any hue can be produced by some combination of three other appropriately-chosen lights. As amazing as it seems, the colors on a TV screen are actually made by adding together just three lights - usually varying amounts of red, green, and blue. (On old-school large-projection TVs you can see the three separate lights that combine on the screen to produce all the colors you see in the picture. Other cathode ray TVs work the same way, but the three colored beams are inside the picture tube so that you can't see them directly, only their mixtures on the screen.) Thus, when you used to adjust the color control features on your TV, you were actually changing colors by mixing different amounts of these three lights.

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Lecture Launcher 3.6 - Eyes and Camera Lenses

A popular belief among laypeople (and, for a time, even among scientists) was that the eye worked like a film camera. That's understandable; there are some similarities in the functioning of the eye and the original design of a camera. For instance, both the pupil of the eye and the aperture of a camera contract and expand in response to a respective increase or decrease in the amount of light entering the apparatus. But when you compare the human eye to a traditional film camera, some of the differences between the two are striking.

Perhaps the strangest difference between the eye and a camera is the positioning of the retina and analogous film. For a camera to be like the human eye, we would have to load our film into the camera backward. That is, the photoreceptors actually pick up the light off the back surface of the eyeball.

A camera must be held relatively steady to capture a clear image, but when the eyeball is held steady, the image disappears.

Both the camera and the eye have a lens that focuses an image on a surface, but they have different methods of focusing. The lens in a camera moves closer to or farther from the film in order to focus the image on the film; the lens of the eye changes shape to focus the image on the retina. This process in the eye is called accommodation.

An upside-down mirror image is focused on both the film and the retina. The film and the retina differ, though, in that film records an image exactly as projected. The photoreceptors in the retina receive information from the visual stimuli that is analyzed and reconstructed as it moves through the visual system from the retina to the cortex. What we perceive is a picture that is *not* identical to the item we are looking at. Photographs in which people have their feet extended closer to the camera in front of them are comical because the feet look so big. When the eye processes the same scene, the feet do not look unwieldy because we take relative distances into account and perceive the feet as being a constant size.

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Lecture Launcher 3.7 - The Eye Exam

Ask students to share their experiences with eye exams. Those who have ever been fitted for eyeglasses will have experienced a type of difference threshold. Examinees look through a large pair of "binoculars" to check for the best lenses. Ask if students remember being asked as they looked at the visual display, "Can you tell the difference between Lens 1 and Lens 2? Lens 1? Lens 2?" The doctor was, in effect, checking for JND. Ask students to share how well they believe they were able to perceive the difference between alternative lenses if they felt rushed by the doctor. Their responses will help you introduce the idea that sensations and perceptions, though governed by psychophysical laws, are influenced to some degree by emotions. But before discussing such factors, it's important to grasp the basic processes of sensation and perception. To begin with, it's important to understand the difference between the two: Sensation is the physical experience of seeing or hearing or sensing in some other way; perception is the psychological process of giving meaning to what has been sensed.

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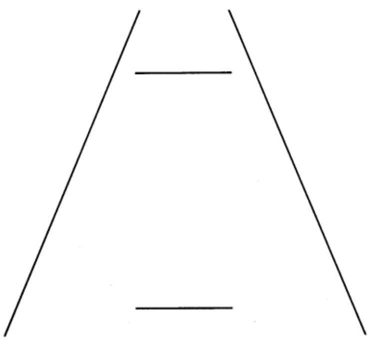
Lecture Launcher 3.8 – 2D, 3D…Can it Produce 4K Ultra HD?

Many of the so-called *geometric illusions* (e.g., the Ponzo illusion or the Muller-Lyer illusion, pictured below) are a result of the massive and critical task of transforming two-dimensional retinal images into a three-dimensional percept. In the case of the Ponzo illusion, the line at the top (in the middle of the converging lines) is seen as longer than the line at the bottom (although they are both physically the same length). The explanation is that, in the natural environment, images become smaller and parallel lines (e.g., train tracks) converge with increasing distance from us. Therefore, in the "real world," when two objects have the same image size on the retina and one is perceived as being much farther away than the other, the one that is farther away must be larger. Via the 2-D to 3-D transformation by the visual system, we perceive the top line in the Ponzo illusion as being farther away, thus it appears compellingly longer.

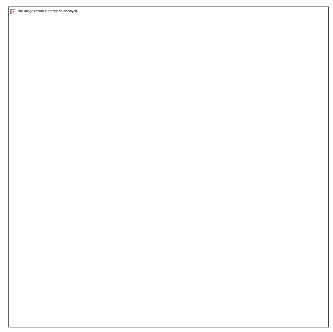
For the Muller-Lyer illusion, the lines drawn between the angles are physically the same length. The line bisecting the angles flanked outward, however, appears longer. Again, the explanation involves the visual system's conversion from 2-D to 3-D. These kinds of angles (although not readily perceived) are found in corners of rooms—the outward flanked angles are most often perceived as belonging to a corner of a room that is pointed away, whereas the inward flanked angles are most often perceived as a corner that is pointed toward us. Because we assume that the corner that is pointed away from us is farther away, the line belonging to that image (although physically equivalent) appears longer than the line belonging to the corner that is pointed toward us.

A discussion of the 2-D to 3-D conversion, including these illusions and explanations, will serve to enhance students' concept of perceptual representation. It should also lead students to critically examine their own beliefs regarding perception versus reality.

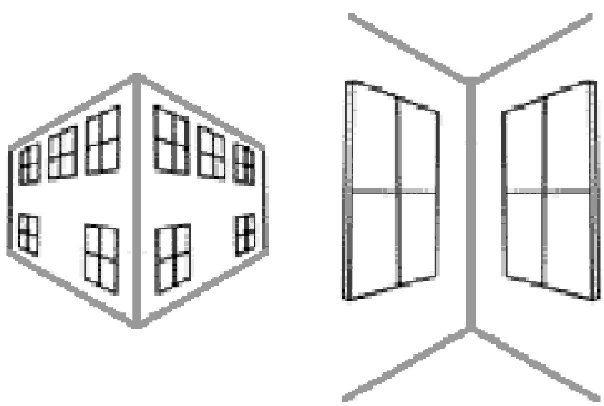
The Ponzo illusion



The Muller-Lyer illusion



Another version of the Muller-Lyer illusion



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Lecture Launcher 3.9 - Auditory Agnosia: The Case of C.N.

A counterpart to P.T. (mentioned above) is C.N. Here's her story:

Over a 3-month period, a 35-year-old nurse, C.N., suffered two aneurysms, one in the left middle cerebral artery and another in the right middle cerebral artery. After surgery to drain the "ballooning" of the arteries, she complained that her perception of music was impaired, despite her ability to comprehend and produce speech and detect tones. She could not recognize melodies from her own music collection, nor could she recognize familiar, popular songs, including the Canadian national anthem "O Canada." Further tests confirmed her *amusia*, or impairment of music abilities with no impairments of long-term memory. Interestingly, she could identify the song title if given the written lyrics, and could name the artist when told the song title. C.N. was able to recognize environmental sounds, such as human voices, transportation sounds, and animal cries. Furthermore, it appears that C.N.'s *amusia* is limited to recognizing melodies; she performed as well as normal subjects when asked to judge if two tones were of the same rhythm. And, despite her inability to recognize melodies, she still loved to dance.

Gazzaniga, M. S., Ivry, R. B., & Mangun, G. R. (2013). *Cognitive neuroscience: The biology of the mind.* (4th ed.). New York: W. W. Norton & Company.

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Lecture Launcher 3.10 - Perfect Pitch

Absolute pitch, or what is commonly called "perfect pitch," is the ability to identify the pitch of a musical tone without the need to hear another tone for reference. Absolute pitch occurs in about 0.1% of the population, and those who have it tend to have been raised in a musical family and their absolute pitch had been discovered before age 10 (Profita & Bidder, 1988). Individuals with absolute pitch are more likely to become eminent musicians and composers compared to individuals without absolute pitch. Additionally, individuals who do not have absolute pitch apparently cannot develop it later in life, suggesting a critical period for the development of absolute pitch. Profita and Bidder found that absolute pitch is inherited, suggesting that it may be at least partly determined by a single dominant gene. The dominant gene may trigger brain development that better allows for pitch analysis.

There are differences in brain anatomy in individuals with perfect pitch compared to those without perfect pitch. In most individuals a section of the temporal lobe, called the *planum temporale*, is larger in the left hemisphere than in the right hemisphere; Wernicke's area is located in the left *planum temporale*. Generally, the left hemisphere is specialized for making absolute, categorical judgments, such as distinguishing between *r* and *s* sounds. The right hemisphere is specialized for making relative judgments, such as judging whether one line is shorter than another. Because individuals with perfect pitch are able to make absolute judgments about the pitch of a musical tone, one might predict that some area(s) of the left hemisphere, which specializes in absolute judgments, may be larger or different in individuals with perfect pitch. Although research is underway, one study gives us an inkling into the brain areas associated with perfect pitch.

Schlaug et al. (1995) found that this asymmetry was much greater among musicians with absolute pitch than among musicians without absolute pitch or nonmusicians. Specifically, they found the surface area of the left *planum temporale* was 80% larger than that of the right *planum temporale* in musicians with absolute pitch. By comparison, the surface area of the left *planum temporale* was 26% greater than the right for musicians without absolute pitch and 23% greater than the right for nonmusicians. Schlaug and colleagues suggest that individuals have this pitch-analyzing machinery in the left hemisphere, as opposed to the right hemisphere, and this allows these individuals to utilize the left hemisphere to make absolute, categorical judgments about pitch.

Münte, T. F., Altenmüller, E., & Jäncke, L. (2002). The musician's brain as a model of neuroplasticity. *Nature Reviews Neuroscience, 3*, 473-478.
Profita, J., & Bidder, T. G. (1988). Perfect pitch. *American Journal of Medical Genetics, 29,* 763-771.
Sacks, O. (2010). *Musicophilia: Tales of music and the brain*. New York: Random House.
Schlaug, G., Janke, L., Yanxiong, H., & Steinmetz, H. (1995). *In vivo* evidence of structural brain asymmetry in musicians. *Science, 267,* 699-701.

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Lecture Launcher 3.11 - The Mosquito

As we age, damage to the hair cells in the cochlea results in gradual hearing loss. This age-related hearing loss, called *presbycusis*, preferentially affects higher frequency hearing. For example, people younger than 20 can usually hear tones in the 15–18 kHz range, whereas adults older than 25 or 30 usually cannot.

Recently, the fact that teenagers can hear sounds that older adults cannot has been used in several creative ways. In 2005, an inventor named Howard Stapleton created a device called the "Mosquito," which is designed to keep rowdy teenagers from loitering around shops and in other places they may cause trouble. It works by emitting a high-frequency noise that older people cannot hear but that teenagers find annoying. However, use of the Mosquito has been controversial, with some even claiming that the device violates the human rights of teenagers and younger adults. Others are concerned that exposure to the loud, high-frequency noise produced by the Mosquito might actually damage the hearing of children.

In an interesting twist, some teenagers have taken the anti-teenager Mosquito technology and turned it to their advantage. By recording the Mosquito's high-frequency sound, they were able to create a ring-tone called "teen buzz" for their cell phones that cannot be heard by most adults. This means that students using the special ringtone can leave their cell phones on and receive text-message alerts while at school, without the teacher hearing the phones ringing. In a similar application, the developers of the Mosquito system created a dance track with a secret melody embedded in the song that only younger listeners can hear!

Block, M. (2006, May 26). Teens turn 'repeller' into adult-proof ringtone. http://www.npr.org/templates/transcript/transcript.php?storyId=5434687
Calls to ban 'anti-teen' device (2008, February 12). http://news.bbc.co.uk/2/hi/uk_news/7240180.stm
Lyall, S. (2005, November 30). Rowdies buzz off as the Mosquito bites. http://www.theage.com.au/news/world/rowdies-buzz-off-as-the-mosquito-bites/2005/11/29/1133026467657.html
Secret alarm becomes dance track (2006, September 26). http://news.bbc.co.uk/2/hi/uk_news/wales/south_east/5382324.stm

http://www.freemosquitoringtones.org/
http://www.noiseaddicts.com/2011/06/mosquito-ringtones/
http://www.youtube.com/watch?v=1H75hBXvjsw

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Lecture Launcher 3.12 - Is Your MP3 Player Hurting You?

Anyone who has ever worked in a noisy environment, such as on a factory floor, knows that there are often strict rules about how loud the sounds workers are exposed to can be, and for how long workers can be exposed. This is because long-term exposure to loud sounds can damage the sensitive hair cells in the inner ear. After they are damaged, hair cells are not replaced, resulting in permanent hearing loss.

Although noise exposure in the workplace is a long acknowledged danger, a much more recent concern is listening to personal music players (such as the iPod) through headphones. The popularity of these devices, combined with the number of hours many people -- especially teenagers -- use them, have led many hearing specialists to worry about the safety of the players. There is evidence to suggest that 5%-15% of headphone users listen to their music players at levels and lengths of time that are considered unsafe. Potentially, this could lead to an epidemic of hearing disabilities in the future.

Given the potential long-term danger to hearing, some experts have recommended limiting by law the maximum volume on personal music players. Others, however, feel that this might be an oversimplification of the issue. This is because the risk to the listener is not just a function of the device's volume, but other factors as well. For example, a 90 dB sound may be considered a relatively safe level when listening to music through headphones for a few hours, but exposure to 90 dB for 8 hours in a day may cause hearing loss. Also, the type of headphones used can increase or decrease the loudness. Earbud style headphones tend to increase the loudness of the music compared to other styles of headphones when the volume control is kept at the same level. (Although earbud headphones can increase the maximum volume possible, studies have shown that, when using earbud-style headphones, listeners typically keep the volume setting lower than those who use headphones which do not enter the ear canal. This indicates that earbud headphones are probably of no greater risk to users.)

After Introducing students to the potential dangers of personal music players to their long-term hearing, ask students to debate what policies, if any, should be implemented to prevent a potential epidemic of hearing loss. In particular, encourage students to share their opinions on whether the maximum volume of these devices should be regulated. What are some problems with this approach? Is there a danger that it could create the false impression that listening to music at the maximum legal volume setting is safe for extended periods at a time?

Fligor, B. (2007). Hearing loss and iPods: What happens when you turn them to 11? *The Hearing Journal, 6* (10) , 10-16.
Kenna, M. A. (2015). Acquired hearing loss in children. Otolaryngologic Clinics of North America, 48(6), 933-953.
Walker, E. J., Lanthier, S. N., Risko, E. F., & Kingstone, A. (2012). The effects of personal music devices on pedestrian behaviour. *Safety Science, 50(1)*, 123-128.

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Lecture Launcher 3.13 - Hear, Here, and Over There

We use our ears to point our eyes in the direction of sound-producing events. For this to happen the auditory system must be able to perceive the direction from which a sound is coming, and its perception of space must somehow be integrated with the visual system's perception of space. Unlike an eye, however, an ear has no direct coding of spatial direction. Information about the sound's direction is perceived by comparing the stimulation in one ear with that in the other. In this respect, sound localization is a lot like the visual depth cue of binocular disparity.

There are two basic sources of information about sound coming from the left or right: the sound entering one ear differs from that entering the other in both *intensity* and *time*. When a sound comes from directly in front of your head, its intensity is equal at your two ears. In the case of high-frequency sounds coming from the side, your head creates a “sound shadow,” making the sound less intense at the far ear than at the near one. It is only for high frequencies that there is information about how far to one side or another a sound is located.

The other primary source of information about the horizontal direction of a sound is the time at which it arrives at your two ears. When a sound comes from directly in front of your head, the arrival times are the same because your two ears are the same distance away from the sound. When it comes from the side, however, the sound wave must travel farther to reach the ear on the far side. Even though this extra distance takes only a little extra time - less than one thousandth of a second - it is enough to tell us which side sound is coming from.

The direction of sounds from left to right is probably the most important part of spatial hearing, but it isn't the only part. You can also tell whether a sound is coming from above or below: the sound of a jet streaking overhead or of an object dropped at your feet. You are not able to perceive vertical direction from simple arrival times or intensities, however. It is the shape of the external ear (or pinna) that apparently allows you to perceive the vertical dimension of space.

We are left with the problem of perceiving the third dimension of depth: how far away the source of a sound is from us. A sound that is near is louder than one that is far away, so you might think that intensity would provide all the information you need about the distance (or depth) of the source of a sound. Unfortunately, it is not so easy. A low-intensity sound at the ear might have come from either a loud sound far away or a soft one nearby. (The situation here is analogous to the relations among retinal size, object distance, and object size in visual perception.) If the sound is one whose usual intensity you know (such as someone speaking in a normal voice or the sound of an average car engine), you can perceive its approximate distance auditorily using intensity information. If the sound is one whose usual intensity you do not know, however, you can't tell how far away it is by hearing it: you have to look. But because you can hear the direction a sound is coming from, you can use your ears to point your eyes, which can then do the job judging the distance. This is a good example of how your senses work together to provide you with knowledge of the world.

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Lecture Launcher 3.14 - Sniffing Out the Truth About Fragrance

Devotees of New Age practices such as aromatherapy claim that various fragrances can have a dramatic impact on one's health, well-being, and psychological state. Makers of the air fresheners pretty much claim the same thing, except that the peace of mind comes from successfully masking offensive odors in the environment. Although both camps agree that aromas can impact behavior and mental states, neither has been that forthcoming with proof of these claims.

Social psychologist Robert A. Baron long ago rose to the challenge of investigating such claims, and conducted several studies on the effects of fragrance on behavior. For example, participants in one study were angered or not angered by either a male or female confederate. The participants were later given the opportunity to aggress against the instigator under one of three conditions; in the presence of perfume (a very pleasant scent), in the presence of pine-scented aerosol (a mildly pleasant scent), or in the absence of any pleasant scent. When the confederate was a man, results indicated that aggression was enhanced in the perfume condition if the participants had been angered, but reduced in this same condition if the participants had not been angered. When the confederates were women, however, aggressive retaliation was enhanced by the perfume regardless of whether participants had been previously angered. These findings may be attributed in part to the heightened arousal that is often experienced in the presence of fragrances. In a subsequent set of studies, Baron investigated the effects of pleasant fragrances on the work environment. Participants completed a word task under conditions of either high or low stress, and in the presence or absence of a pleasant fragrance (*Powder Fresh* or *Spiced Apple* air fresheners). In both stress conditions, the presence of the fragrance significantly enhanced performance.

What causes fragrances to have such effects? Baron suggests that pleasant fragrances act as a mild mood enhancer, one at least as effective as other mood manipulations. An additional experiment, for example, had participants complete an anagram task under low or moderate stress and in the presence or absence of a fragrant air freshener (lemon and floral scents were used). In this experiment, a small gift of candy was also presented to some participants. The results revealed that both the fragrances and the small gift significantly improved performance on the word task, under conditions of either moderate or low stress. In short, the effects of the fragrance seemed to match those of the gift (a known positive mood enhancer). In fact, both the fragrance and the gift increased participants' willingness to help the experimenter in this study as an unpaid volunteer.

Based on his research, Baron for a time developed and marketed the PPS® (Personal Productivity/Privacy System), a small unit that provides filtration of allergens, generates white noise to mask conversations, and releases a pleasant fragrance into the air.

Baron, R. A. (1980). Olfaction and human social behavior: Effects of pleasant scents on physical aggression. *Basic and Applied Social Psychology*, *1*, 163-172.

Baron, R. A., & Bronfen, M. I. (1994). A whiff of reality: Empirical evidence concerning the effects of pleasant fragrances on work-related behavior. *Journal of Applied Social Psychology*, *24*, 1179-1203.

Baron, R. A., & Thomley, J. (1994). A whiff of reality: Positive affect as a potential mediator of the effects of pleasant fragrances on task performance and helping. *Environment and Behavior*, *26*, 766-784.

Doucé, L., & Janssens, W. (2013). The presence of a pleasant ambient scent in a fashion store: The moderating role of shopping motivation and affect intensity. *Environment and Behavior*, *45*(2), 215-238.

Privitello, U., Fabio, R. A., Nucera, S., & Plebe, A. (2016). The sweet smell of altruism. Correlations between smells and prosocial behaviour. A short review. *RSL – Italian Journal of Cognitive Sciences*, *3*(2), 301-316.
https://www.psfk.com/2010/06/singapore-airlines-sensory-branding.html

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Lecture Launcher 3.15 - Smell Myths

Human smell has often been characterized as being deficient when compared to the smell abilities of some lower organisms. Summarized below are four myths about human smell that have been contradicted by research.

Myth 1: Human smell is less sensitive than that of other animals

Research indicates that the individual smell receptor cells in humans will respond to a single odorant molecule. The difference in overall sensitivity appears to be due to the fact that some lower organisms, such as dogs, have more smell receptors.

Myth 2: Humans have a relatively poor ability to detect changes in smell intensity

Although earlier research indicated that the difference threshold for smell was the largest of all the senses, more recent research, carefully controlling the concentrations of the smell stimuli, indicated that difference thresholds were equal to or lower in size than those for other senses.

Myth 3: Odor identification ability is poor in humans

Although early research indicated that the ability to recognize previously presented odors was poor, this result may be related to the fact that unfamiliar odors were used as the stimuli. Odor identification accuracy is primarily a function of labeling, not smell. That is, if subjects are given the correct label of an odor when they are first exposed to it, their ability to later identify the odor is significantly improved.

Myth 4: Although many animals use odors to communicate, humans do not

Several studies have demonstrated that individuals are able to identify correctly about 75% of the time whether odors associated with sweat or breath came from a male or female. Menstrual synchrony, a phenomenon in which women who live in close proximity for a period of time begin to have similar starting times for menstruation, has also been found to be related to smell.

Goldstein, E. B. (1989). *Sensation and perception* (3rd ed.). Belmont, CA: Wadsworth.

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Lecture Launcher 3.16 - Noses, Aisle 12

A childish joke runs something like this:

Puerile yuckster: “Did you pick your nose when you were a kid?”
Unsuspecting patsy: “Yeah, sure.”
Puerile yuckster: “Well, why didn’t you pick one that was smaller?!”

If chemist Nate Lewis has his way, soon we all can pick noses smaller than a dime to sniff out scents as large as we please. And he’s not joking.

Lewis and his colleagues at the California Institute of Technology developed an artificial nose, research motivated partly by the challenge and partly by practicality. The challenge is that smell remains the least studied and least understood of the senses. Although relatively primitive (compared to the sophisticated intricacies of vision), scientists still don't have a complete understanding of the rules governing how smell works. To that end, Lewis and his colleagues have created a variety of artificial noses, ranging from tiny "noselets" to bookcase-size monstrosities. Each is dedicated to the task of detecting various scents, odors, and stinks in the environment.

That's where the practicality comes in. Smell is big business, from truffle-sniffing pigs to deodorant testers to perfume evaluators to rotten food detectors. Currently this work is done by humans (well, not the truffle-finding) whose noses tire quickly and who aren't equally sensitive to all odors. A reliable artificial nose would allow industry to perform a variety of important tasks cheaply and efficiently. What's more, Lewis envisions a day when small artificial noses will detect carbon monoxide in your home, rotting foods in your refrigerator, leaking fluids in your car, or peptic upset from your breath. In fact, John Glenn's 1998 NASA mission included a prototype of Lewis' artificial nose to sniff space air for potential health hazards.

Here's how it works. Chemists have known for some time that industrial plastics swell when they absorb a chemical odor. This is not earth-shaking; all polymers do that. However, specialized plastics that conduct electricity could be used to create a unique pattern of electrical activity for each chemical scent. By combining different plastics that generate different electrical signals, a fairly accurate "scentprint" would result for each odor. However, there are a finite number of electricity-generating plastics, so Lewis and his team have switched instead to cheap industrial plastics combined with soot particles to generate electric current. When hundreds or thousands of these units are combined in a single detector, the result is a cheap, mass produced, rugged, yet highly sensitive nose.

Some of these developments are years away, but several research and industry teams have joined the search for an artificial nose. Unfortunately, the answer may not be as plain as …well, you know.

Burl, M. C., Doleman, B. J., Schaffer, A., & Lewis, N. S. (2001). Assessing the ability to predict human percepts of odor quality from the detector responses of a conducting polymer composite-based electronic nose. *Sensors and Actuators B-Chemical*, *72*, 149-159.

Doleman, B. J., & Lewis, N. S. (2001). Comparison of odor detection thresholds and odor discriminablities of a conducting polymer composite electronic nose versus mammalian olfaction. *Sensors and Actuators B-Chemical*, *72*, 41-50.

Fitzgerald, J. E., Bui, E. T., Simon, N. M., & Fenniri, H. (2017). Artificial nose technology: Status and prospects in diagnostics. *Trends in Biotechnology*, *35*(1), 33-42.

Matzger, A. J., Lawrence, C. E., Grubbs, R. H., & Lewis, N. S. (2000). Combinatorial approaches to the synthesis of vapor detector arrays for use in an electronic nose. *Journal of Combinatorial Chemistry*, *2*, 301-304

McFarling, U. L. (1999, February 20). Chemist wants to place noses in your car, house. *Austin American-Statesman*, A21, A24.

Son, M., Lee, J. Y., Ko, H. J., & Park, T. H. (2017). Bioelectronic nose: An emerging tool for odor standardization. *Trends in Biotechnology*, 35(4), 301-307.

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Lecture Launcher 3.17 - The (Dis)embodiment of Fear

Summaries of research on sensation and perception traditionally have focused on vision and hearing as the two "main" human senses, often to the exclusion of an extended discussion of the chemical and motion senses. Although the present chapter provides good examples of the workings and importance of the "other" senses, your students might gain a better appreciation of their significance through a case study.

Oliver Sacks reported the case of the "disembodied lady," a woman suffering from a total disruption of her proprioceptive system. A day before gallbladder surgery, a young woman of 27 suddenly experienced bizarre symptoms unrelated to her medical condition. She was unable to hold anything in her hands, was unsteady on her feet, and found that her arms flailed about whenever her attention was directed elsewhere. She lay motionless and expressionless in the hospital bed, complaining of experiencing a strange sense of disembodiment. After initial psychiatric opinions of preoperative anxiety and hysterical conversion, it was determined that the woman was suffering from *acute polyneuritis.* An extremely rare condition, it is characterized by a shutting down of the proprioceptive receptors; in short, a lack of muscle, tendon, and joint sense. As a consequence, the young woman lacked position sense, leaving her literally with one hand not knowing what the other was doing. In fact, she didn't know where her hands *were*, or legs, or arms, for that matter. In absence of feedback from the proprioceptive system her parietal lobes, though functioning quite normally, had no data to function on, leaving her in a truly "disembodied" state.

Many senses contribute to the experience of one's body: vision, vestibular senses, proprioception. With the disruption of one of these the others became more vital. In order to "know" the location and arrangement of her own body parts, the woman had to have them in direct sight. Thus, seeing her hands in front of her face supplied the only information about where her hands were. Similarly, walking, eating, talking, expressing emotion, or performing any of the other simple bodily actions we take for granted required the utmost diligence and concentration. Her sense of disembodiment was just that; she was left feeling much like a lump of clay.

Although this case is rare, and certainly bizarre, it provides food for thought. We can close our eyes to simulate blindness, or wear plugs to provide hearing or olfactory impairment, but it is difficult to imagine how not to experience one's body. But in imagining how this might feel (or, *not* feel, as the case might be), we can better appreciate the importance of these "hidden" senses.

Sacks, O. (1985). *The man who mistook his wife for a hat*. New York: HarperCollins.

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Lecture Launcher 3.18 - New Hope for the Paralyzed

Hocoma AG, a Swiss company, has developed a device called the Lokomat. It is an exoskeleton that allows patients with partial damage to the spinal cord to walk on a treadmill, improve cardiovascular function, reduce swelling in the legs, and generally build confidence. Confidence doesn't come cheap: A Lokomat runs about $250,000. In comparison to a team of physical therapists and other specialized equipment that are currently used in rehabilitation, that price may be cheap in the long run—in fact, a small price to pay for the promise of restored mobility.

Meanwhile, researchers at Duke University have reported success with a brain implant that allows monkeys (and, in trials, some humans) to move a robotic arm using their thoughts alone. This science fiction scenario not only holds the promise of remote action in specialized situations (such as mentally controlling a bomb-defusing robot) but also has day-to-day applications in the life of the paralyzed. Imagine being able to send a mental command to a robotic arm to feed oneself or, possibly, sending mental signals to an exoskeleton to cue coordinated muscle movements to accomplish walking. Right now, the monkeys who have been tested are successful at performing simple tasks, comparable to their earlier training using a joystick. But more complex applications, such as using wireless devices, processors with greatly enhanced power, or even commands sent over the Internet, remain in the realm of possibility.

Finally, on a related note, researchers from the Georgia Institute of Technology and the University of Western Australia have created a robotic arm that creates "art" from signals generated from rat brain cells. Weird? You betcha! The brain cells are kept in a Petri dish in a lab in Atlanta, and their impulses are sent over the Internet to the mechanical arm that translates the signals into abstract squiggles and lines. Although the creations won't win any blue ribbons, the scientists are much more interested in the biology of it all than the artistic merits. By studying how brain impulses work in concert with one another, the work may eventually lead to breakthroughs in the mental control of remote behavior.

Cimolin, V., Vagnini, A., Germiniasi, C., Galli, M., Pacifici, I., Negri, L., ... & Piccinini, L. (2016, September). The Armeo Spring as training tool to improve upper limb functionality in hemiplegic Cerebral Palsy: A pilot study. In *Research and Technologies for Society and Industry Leveraging a better tomorrow (RTSI), 2016 IEEE 2nd International Forum on* (pp. 1-4). IEEE.

Donati, A. R., Shokur, S., Morya, E., Campos, D. S., Moioli, R. C., Gitti, C. M., ... & Brasil, F. L. (2016). Long-term training with a brain-machine interface-based gait protocol induces partial neurological recovery in paraplegic patients. *Scientific Reports*, *6*.

Esquenazi, A., Maier, I. C., Schuler, T. A., Beer, S. M., Borggraefe, I., Campen, K., ... & Wirz, M. (2016). Clinical application of robotics and technology in the restoration of walking. In *Neurorehabilitation Technology* (pp. 223-248). Springer International Publishing.

Guan, X., Ji, L., & Wang, R. (2016, January). Development of exoskeletons and applications on rehabilitation. In *MATEC Web of Conferences* (Vol. 40). EDP Sciences.
Keefe, B. (July 13, 2003). What is a 'semi-living artist?' Rat brain cells and a robot arm. *Austin American-Statesman*, A17.
Stengle, J. (October 18, 2004). Exoskeleton helps paralyzed Dallas man walk again. *Austin American-Statesman*, B6.
Weiss, R. (October 13, 2003). In study, monkeys move robotic arm with thoughts. *Austin American-Statesman*, A1, A12.

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▼CLASSROOM ACTIVITIES, DEMONSTRATIONS, AND EXERCISES

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Activity 3.1 - Pressure Phosphene

Sometimes students have difficulty distinguishing, in a real sense, sensation from perception. Partly it is because of semantics—often people will use the term *sensation* when they mean *perception*. For example, people will refer to a "tingly sensation," or "warm sensation" when in fact the basic conscious realization that something (feeling, seeing, hearing, etc.) is occurring is perception. Sensation is the front-end of the process: the conversion of energy or substances into patterns of neural discharges. Perception occurs when the brain makes sense of these patterns of neural discharges.

A nice way to demonstrate the distinction between sensation and perception is to have students produce their own pressure phosphenes. Pressure phosphenes illustrate Johannes Muller's doctrine of specific nerve energies. Briefly, the doctrine states that if you stimulate (say with electrical current) a taste receptor that normally responds to sweet, you will perceive a sweet taste. For vision, if you stimulate a photoreceptor with a slight amount of pressure (as opposed to light, its natural stimulus) you will perceive light! This is called a "pressure phosphene." The easiest way to produce a pressure phosphene is to have students close their left eye, and look at their nose with their right eye. Then, using the index finger of the right hand, have students repeatedly press gently the outside corner of their right eye (they should press on the outside corner of the eye lids, not directly on the eyeball). This doesn't require much pressure at all. One should observe a round patch of light that appears to the left of the tip of the nose. Remember to remind students to repeatedly (lightly) press or tap.

The first reaction to this demonstration is usually "wow," or "cool." From a pedagogical standpoint, the fascinating aspect of this demo is the fact that we are able to produce a sensation of light when no light exists! Because the sensory receptors responsible for vision have been activated, they carry out their "duty -- sensation -- and the brain assumes that the series of neural impulses it receives is light (perception).

Another critical point to note is the fact that the light appears on the opposite side of where the pressure is applied…why is this? – (this is a good question to ask students). Of course, the reason is that images are focused onto the retina in such a way that they are reversed and inverted (relative to the outside world). So, those light rays that normally reach the photoreceptors corresponding to the pressure stimulated ones in the demo, come from the left visual field. Hence, we perceive the light as coming from the left!

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Activity 3.2 - Beware of What You Wish For

This exercise encourages creativity and stimulates students to think about the evolutionary purposes of sensation, and meditate on how an optimal level of sensory acuity depends on the purposes for which the senses are needed. The student handout for this exercise, in which students imagine how their sensory world would change if their sensory receptors were more acute, is included as **Handout Master 3.1**. Suggested answers are listed below.

1. Instead of a world of substantial objects, you might see groups of colliding molecules, and as a result, you might hesitate to sit on a chair because it would not look solid. You might see through walls, like Superman. It would be disconcerting to see your lover's liver and kidneys at work. You might lose the illusion of solid patches of color on TV if yellow appeared as rows of red and green dots. You might lose the illusion of movement in movies and television, by seeing the individual frames with pauses between. Spontaneous activity in the visual cortex might cause you to see flashes and spots of light when you close your eyes or are in complete darkness. You might see ultraviolet, infrared, and radio waves. You might see germs and bacteria on everyone; nothing would ever look clean again.

2. You might hear your heart beating, the blood pumping through your arteries and veins, the food in your stomach being digested, your intestines at work--and perhaps even molecules banging against each other. You might hear your next-door neighbors talking about you, and music emanating from the houses on your block and passing cars. The sounds of airplanes, leaf blowers, jack hammers, etc., might be unbearable. You might hear water passing through pipes and electricity passing through wires. You might hear your house groaning as it expands and contracts with changes in temperature. And because of all this, you might have trouble sleeping, studying, and maintaining your sanity.

3. Tastes would be too strong, and the bad taste in your mouth in the morning would be extremely unpleasant. You might taste stray molecules floating around in the air. You might smell the residue of food that rotted in your refrigerator a year ago. You would smell the scents left by animals almost everywhere, and you wouldn't dare go near a pig pen or a fish cannery. You could smell other people's soap, shaving cream, toothpaste, and natural odors from across the room. You might find yourself somewhat disgusting.

4. Our senses have evolved in the way they have in order to maximize our chances for survival. For example, because we are diurnal (awake in light) we have many cones on the retina; nocturnal animals need mainly rods. Because we evolved as carnivores (hunting and eating meat), our eyes are close together so the overlapping visual fields can provide good depth perception. There is only so much room inside the human skull, which means that for any additional sensory capacity, something else must be sacrificed. For human beings, language is more important to survival than smell.

5. Over several million years we might lose some abilities and gain others. For example, because the range of sounds is somewhat different in the urban jungle than in a real jungle, we might become more sensitive to certain sound wave frequencies and less sensitive to others. We might lose our aversion to bitter tastes because we no longer forage for berries and don't often have to discriminate instantly between poisonous and nonpoisonous foods. If pollution resulted in everyone living under large domes with temperature control, cutaneous sensitivity to atmospheric conditions might become necessary. However, changes in sensory systems will occur only if certain genes give the individuals who carry them an advantage over others in living to maturity and reproducing. It would probably take a major environmental change to produce this kind of advantage.

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Activity 3.3 - Variability in the Absolute Threshold

Students can experience the concepts of threshold and variability in the absolute threshold at home. Ask students to place a watch or clock with a subtle ticking sound on a table in a quiet room. They should move away from the clock, then move closer to it until they just hear the ticking. If they stand there for a while, they will notice that they won't be able to hear the ticking on occasion, and they will need to step forward to hear the ticking. At other times, the ticking may seem "too loud" and they might have to step back until they hear the ticking of the clock only 50% of the time.

You may try this in class with a few student volunteers who position themselves around the room, and very quiet classmates. You will need a clock with a ticking second hand.

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Activity 3.4 - Sensory Adaptation

Our senses automatically adjust to the level of stimulation they are receiving so that they can be as sensitive as possible without getting overloaded. As a result, our senses become less sensitive when the overall level of stimulation is high, but more sensitive when the overall level of stimulation is low. This explains, for example, why the tick of a watch is more annoying in a quiet room than on a busy street. This phenomenon of sensory adaptation can be readily illustrated in class with a variety of senses, including touch, taste, and vision. Depending on your class size (e.g., if you have fewer than 30 or 35 students), you could allow all students to participate in the first two exercises or for larger classes you might prefer to select a subset of volunteers.

Touch. Fred Whitford suggests a simple exercise for demonstrating sensory adaptation with touch. Bring to class a number of samples of very coarse sandpaper and distribute them to students. After rubbing their index fingers gently over the paper a few times, they should rate its coarseness on a scale from 1 (*very soft*) to 7 (*very coarse*). After a minute or two, have them rub the same finger over the paper and again rate its coarseness. Their senses should have adapted to the coarseness and thus the ratings for the second time should be lower.

Taste. A different exercise (suggested by John Fisher) can be used to demonstrate sensory adaptation with taste. You'll need to bring to class (a) a pitcher containing a strong solution of water and sugar, (b) a pitcher containing fresh water, and (c) several Dixie cups. Distribute two Dixie cups to each student and fill one with sugar water and one with fresh water. Instruct students to take a sip of the sugar water and to swish it around in their mouths for several seconds without swallowing it; gradually it should taste less sweet. After swallowing it (or spitting it back into the cup), students should then taste from the cup containing fresh water. Students will be shocked at how incredibly salty the water tastes and will wonder if you didn't spike it with salt when they weren't looking! Explain that when the overstimulated taste buds responsible for sweetness became temporarily less sensitive, the taste buds responsible for salt became more prominent as a result.

Vision. A final exercise requires a little more effort but powerfully illustrates sensory adaptation in vision. Davis and Grover (1987) first described this activity, a modified version of a procedure developed by Hochberg et al. (1951), that uses a *Ganzfeld* (a homogenous visual field) to demonstrate that the visual system requires varied stimulation to prevent sensory receptor adaptation. To conduct this demonstration you will need to make a Ganzfeld and have a red light source, such as that on a stereo or coffee maker. The Ganzfeld is constructed using a ping pong ball. Cut the ping pong ball in half and discard the side with the writing on it. Then attach cotton around the rim of the remaining half in order to protect the student's eye. Instruct a student volunteer to place the Ganzfeld on one eye, touch the Ganzfeld on the red light, close their other eye, and continue to stare at the red light, reporting any experience that occurs. After a minute or so, although the light is still on, the student will state that you have turned the red light off. Explain to your students that this effect is the result of receptor adaptation because of the Ganzfeld.

Davis, S. F., & Grover, C. A. (1987). And then the lights went out: Constructing a simple Ganzfeld. In V. P. Makosky, L. G. Whittemore, & A. M. Rogers (Eds.), *Activities handbook for the teaching of psychology: Vol. 2* (pp. 49-50). Washington, DC: American Psychological Association.
Fisher, J. (1979). *Body magic*. Briarcliff Manor, NY: Stein and Day.
Hochberg, J. E., Triebel, W., & Seaman, G. (1951). Color adaptation under conditions of homogeneous visual stimulation (Ganzfeld). *Journal of Experimental Psychology, 41*, 153-159.

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Activity 3.5 - Sensation

In this exercise, students apply various phenomena associated with sensation to everyday examples. The student handout for this exercise is included as **Handout Master 3.2**.

Answers:

1. Distribution of receptors: Sensitivity is associated with the number and concentration of receptors. The fingertips and lips have many densely packed touch receptors. The lower back has relatively few, and the brain has none.

2. Difference threshold: The smallest difference in stimulation that can be reliably detected by an observer when two stimuli are compared is called the difference threshold. Apparently, the difference in sweetness among the three cups allows one to be perceived as distinct but is insufficient for discriminating between the other two.

3. Signal detection theory: Signal detection theory indicates that active decision-making behavior is involved in the absolute threshold. The tiredness, as well as attention, of subjects may be affecting such behavior.

4. Sensory adaptation: A reduction in sensitivity results from unchanging, repetitious stimulation. John may be having trouble feeling the glasses on his head because they've been there for awhile.

5. Optimal levels of stimulation: The human brain requires a certain level of stimulation to work most effectively. Stimulation is a matter of change and variety in the environment. Bill's work may be so repetitious that it fails to stimulate him.

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Activity 3.6 - Peripheral Vision

The distribution of photoreceptors across the retina is not uniform. For example, the highest density of receptors is located around the fovea, which is responsible for seeing objects in the center of the visual field. In addition, the majority of the retina's cone receptors are located in this same region. Because a high density of receptors is necessary for good visual acuity, and because cone receptors are responsible for color vision, this should mean that only the objects near the center of our visual field should be perceived clearly and in color. In reality, however, most people perceive their entire visual field to be sharp and colorful. This is an illusion created by the saccadic movements of the eye, which collect color and fine detail information from all around, which the brain then combines into a seamless, uniform visual experience.

Begin by reviewing the distribution of photoreceptors on the retina and how this should affect our visual experience. Explain to students that you will demonstrate that the human eye is incapable of detecting details and color from objects in our peripheral vision. Select a volunteer from the class and ask him or her to sit in a chair facing the class. Instruct the volunteer to pick a point in front of them and to foveate (i.e., stare directly at) that point for the duration of the demonstration. Then, take a playing card and hold it about 2 feet from the side of the volunteer's head, just out of their peripheral vision. Tell the volunteer to inform the class when they can determine any of the playing card's features (color, suit, or value). Then, slowly bring the card into the volunteer's visual field, while maintaining the same distance between the card and their head. Remind your volunteer that they should continue to look straight ahead, and not to look at the card directly. If done correctly, students will be amazed by how close to the center of the volunteer's visual field the card must be before he or she can identify the cards color, suit, and value correctly. Students who wish to replicate the demonstration themselves can do so by selecting a random card without looking at it, holding the card at arm's length from their ear, and then slowly rotating their arm to the front while maintaining the arm's length distance between the card and their head. Again, it is critical that the student look straight ahead while performing the experiment.

Adapted from Dennet, D. (1991) *Consciousness explained.* Boston: Little, Brown and Company.

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Activity 3.7 - The Diagonal Line Effect

Use **Handout Master 3.3** to create the stimuli for this exercise. Make three copies of this handout and cut out the circle stimulus on each one. Arrange the circles so that the lines are vertical within one circle, horizontal in another, and diagonal in the third. Have students stand close to the circles and then back away. As they move away from the circles, the circles with the diagonal lines will appear to be a uniform field of gray whereas the vertical and horizontal lines will remain clearly visible. This demonstration illustrates that our visual system is geared to perceive vertical and horizontal lines more readily than diagonal lines.

If you want to be more quantitative with this exercise, you could measure and record the distances at which each student in your class can just distinguish the horizontal, vertical, and diagonal lines, then calculate the class average for each line orientation, and possibly do a statistical analysis.

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Activity 3.8 - Field Demonstrations

As a simple but involving assignment, ask students to experience instances of perceptual phenomenon that are too difficult to demonstrate in class. Students could, for example, choose 2 demonstrations from among the following and write a short paper describing their experiences and relating them to theory and research presented in the text.

Dark Adaptation. For this demonstration, students should take about 15 index cards and a flashlight that is opaque on all sides (so that light shines only through the front) into a very dark room. After placing all 15 cards over the beam of light, students should slowly remove the cards one at a time until they can barely detect the light. Have them count the number of cards that remain over the light. After a few minutes, the light should begin to look brighter. When this is the case, have students try to add a card and see if they can still see the light. They should repeat this process of gradually adding cards over a 15-minute period. Consistent with dark adaptation, students should be able to detect an increasingly dim light the longer they spend in the dark.

Night Vision and the Fovea. Because rods rather than cones are active in dim light, it is easier to see objects that fall in areas rich with rods (i.e., outside the fovea) than in areas packed with cones (i.e., the fovea). To experience this, students should choose a relatively clear night (with few surrounding bright lights) to observe stars. Specifically, they should locate a relatively dim star so that it is slightly to the right or left of the focal point of their gaze. When students suddenly shift their gaze to look directly at the star, however, it should disappear.

The Autokinetic Illusion. Students can experience the autokinetic illusion (i.e., the apparent motion created by a single stationary object) for themselves by doing the following: Students should first create a very small point of light, either by using a thin, sharp flashlight or by covering a larger flashlight with a piece of cardboard containing a small hole. They should then go into a very dark room and shine the light on the wall about 10 feet in front of them. After a few moments, the light should appear to drift and move around slightly. In a dark room, there are no cues to tell you that the light is stationary. Therefore, the involuntary eye movements that typically go unnoticed in a changing environment cause the stationary object to appear to move.

Temperature Adaptation. Students can easily explore temperature adaptation by locating 3 medium size bowls and filling them with (a) very hot (but not painfully so) tap water, (b) very cold tap water, and (c) a mixture of the very hot and very cold water. Students should arrange them so that their right hand is in front of the cold water, their left hand is in front of the hot water, and the lukewarm water is in the middle. Students should them submerse their hands into the water (right into cold, left into hot) for about 3 minutes. After 3 minutes, they should quickly transfer both hands to the lukewarm (middle) bowl, and they will undoubtedly experience adaptation "first-hand."

Foley, H. J., & Matlin, M. W (2009). *Sensation and perception* (5th ed.). Upper Saddle River, NJ: Pearson.

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Activity 3.9 - In Search of Perceptual Illusions

Although the text provides several examples of the most common perceptual illusions, students often can gain a better understanding of them by actively finding their own examples. Possible ways to document examples include taking photos, cutting clippings out of magazines or newspapers, or by describing the illusion in detail if it is not possible to obtain a sample (e.g., if it was seen in a movie). Real world examples of afterimages, stroboscopic motion, perceptual contrast, Gestalt principles, and monocular cues abound, and students will likely enjoy their quest for the ultimate illusion. An added benefit is that students can share their examples with the rest of the class, who can try to identify the illusion portrayed. This way, all students will have had access to numerous examples outside of the text.

As an alternative assignment, ask students to create or develop their own illusion (i.e., by drawing or painting a two-dimensional picture or by assembling a three-dimensional object). Although the illusion should be unique, it should of course be based on principles from one of the major illusions discussed in the text. As an example, students could create their own reversible figure, illustrate one or more monocular cues (e.g., linear perspective, shadowing) in a drawing or painting, or create new examples of Gestalt principles of perceptual organization such as closure or proximity.

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Activity 3.10 - Explaining the Moon Illusion

Each of us has succumbed to the moon illusion; that is, the feeling that the moon at the horizon is larger than the moon at its zenith (or highest point). According to Margaret Matlin and Hugh Foley, this paradox has been the source of speculation by scientists and philosophers for thousands of years. Although early research has ruled out physical explanations (e.g., light refraction, angle of head or eye elevation), the precise psychological mechanism responsible is still in debate, and at least 8 competing explanations have been offered in the last 20 years. Ask your students to explore these explanations in more detail and to write a 2 to 4-page paper summarizing two or three different perspectives on this illusion. Ask them to identify which of the theories they believe provides the best explanation and why.

Foley, H. J., & Matlin, M. W (2009). *Sensation and perception* (5th ed.). Upper Saddle River, NJ: Pearson.
Weidner, R., Plewan, T., Chen, Q., Buchner, A., Weiss, P. H., & Fink, G. R. (2014). The moon illusion and size–distance scaling: Evidence for shared neural patterns. *Journal of Cognitive Neuroscience*, *26*(8), 1871-1882.

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Activity 3.11 - Using Escher to Illustrate Perceptual Principles

Debra Stein suggests a group exercise that both stimulates critical thinking and increases student interest in the discussion of perceptual processes. Divide your students into groups of 5 and give each group copies of two different M. C. Escher prints. You might want to purchase a book or calendar so that you'll have a enough prints to go around. Instruct your groups to choose a recorder and a spokesperson, and then give them 20-30 minutes to identify any and all examples of the following perceptual principles from the textbook: (a) figure-ground, (b) closure, (c) similarity, (d) continuity, (e) proximity, (f) monocular cues, (g) binocular disparity, (h) superposition, (i) elevation, (j) aerial perspective, (k) linear perspective, (l) texture gradient, (m) convergence, and (n) shadowing. When groups are finished, the spokesperson from each group should briefly present the group's finding to the class. Stein reports several positive benefits of this exercise, including: an increased amount of focused discussion about perceptual processes (due to the group discussions as well as the presentations), an increase in students' understanding of perceptual processes as revealed in test scores, and a tendency for greater application of the material (e.g., her students brought other examples from advertisements and art to class; others created illusions on their own).

Adapted from Stein, D. K. (1995). The use of M. C. Escher and N. E. Thing Enterprises prints to illustrate perceptual principles. Paper presented at the 17th National Institute on the Teaching of Psychology, St. Petersburg Beach.

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Activity 3.12 - Rods and Cones

Cones are sensitive to color but not as sensitive to light. By contrast, rods are sensitive to light, but do not register color information. Thus, in dim light, when the rods are doing most of the work, it is difficult to see colors. To demonstrate this phenomenon, bring in several pieces of construction paper of different colors. Ten minutes before you want to demonstrate this concept, dim the lights until you can just barely see. Then, hold up the pieces of paper and ask the students to write down what color they think that paper is. After you turn on the lights, review the correct colors with your students. How accurate were they?

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Activity 3.13 - Auditory Localization

The benefit of having two good ears, separated by our beefy head, is largely a benefit in locating sounds in space. Our determination of the direction of a sound source is made primarily by comparing the quality of sound that arrives at each ear. Basically two judgments are made: relative loudness and relative timing. After a distinct sound is produced, if the sound seems louder to the left ear than to the right ear and is heard at the left ear before it gets around to the right ear, then the person will decide that the sound came from the left.

To demonstrate this, ask a student to sit in front of you, facing the class. Blindfold the student and move around her or him, making a distinct sound. Snapping fingers works, but a sharper sound, such as clicking together two spoons, works even better. Your student's job is to locate the source of your sound in space. The student can either point in the direction of the sound or try to describe its location verbally. The subject will have little trouble if the sound is produced off to either side, either directly or at an angle. The trouble begins when the sound is equidistant from both ears, such as when the sound is made directly in front of, behind, or above the student. Although the student may realize that the sound is not coming from one side or another, there is little basis for deciding whether the sound is in front, above, or behind when the sound is equidistant from both ears.

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Activity 3.14 - Odor Identification Test

Although people can discriminate among a large number of odors, they have a surprisingly difficult time identifying the source of even the most familiar odors. You can illustrate this fact to your students (many of whom will be skeptical) by conducting a large-scale "smell test." First, gather several (approximately 8-15) dark or opaque containers with lids (empty black film canisters are ideal; as those are getting difficult to come by, make a trip to Target or The Container Store and see what you can scrounge up). Assign a different number to each canister (be sure to make a coding sheet with the correct sources) and place cotton balls in the bottom of each to absorb the smell. Good substances to test include baby powder, coffee, peanut butter, pencil shavings, ammonia, lemon extract, peppermint extract, vinegar, chocolate, coconut, Crayola crayons, Play-Doh, soap, bubble gum, and spices (e.g., cloves, pepper, garlic, cinnamon). Instruct the students to lift the lid but to keep their eyes closed when smelling the canisters. Then pass the canisters around the room and have students mark their responses on a sheet of paper. Your confounded students will have a sense of familiarity ("Oh, I definitely know this one...what is it?") more often than they will have an exact identification. [Note that having students match the smells with a list of possible sources would greatly increase their chances of being successful.] If you have time, tally the number of correct guesses by a show of hands. Do good or poor smellers have any hypotheses about the cause of their abilities (or lack thereof)? Do the results replicate the finding that women generally have a better sense of smell than do men?

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Activity 3.15 - Phenylthiocarbamide

Phenylthiocarbamide (PTC) is a chemical that, to most people, has an unpleasant and bitter taste. In 1931, a DuPont chemist accidentally created a cloud of PTC dust in the laboratory, and was surprised when he was the only one in the lab who did not notice the powder's bitter taste. Further research revealed that only about 70% of people can taste PTC, although this number varies in different populations. Although PTC does not occur naturally in food, the ability to taste PTC does correlate with sensitivity to other bitter foods. In 2003, the single gene responsible for differences in PTC tasting was identified. This gene, called TAS2R38, is responsible for a protein that is part of the bitter taste receptor. Although some controversy exists, the ability to taste PTC is generally considered a dominant trait. This means that non-tasters must be homozygous for the non-tasting version of the gene.

Purchase some PTC strips (these are inexpensive and, like everything else on the planet, are available through Amazon.com and other Internet retailers). If the PTC test kit comes with control strips, distribute these to students first. Have students label these strips '1.' Then distribute the PTC test strips and have students label the strips '2.' Next, tell students to place test strip 1 on their tongues and record their descriptions of the taste. You may also want to have students rank the bitterness on a scale from 1–10. Then have students repeat this process with test strip 2. Record on the board the number of students for whom test strip 2 tasted bitter and the number of students for whom the two strips tasted similar. Then have students calculate the percentage of the class that could and could not taste the PTC. You may also want to explore whether the PTC taste appeared to be more intense for some students than others. The results can be used to facilitate a discussion on individual differences in sensory ability and/or the inheritance of genetic differences.

Wooding, S. (2006). Phenylthiocarbamide: A 75-year adventure in genetics and natural selection. *Genetics 172* (4), 2015-2023.

http://www.genome.gov/Pages/Education/Modules/PTCTasteTestActivity.pdf
http://www.amazon.com/TEST-PAPER-STRIPS-CONTROL-VIAL/dp/B001D7FF5O

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Activity 3.16 - The Role of Smell in Determining Flavor

The rich flavor that we sense from our favorite (and not-so-favorite) foods is derived from a combination of taste and smell. According to the text, without smell we can sense the basic tastes (e.g., bitterness, saltiness, sourness, sweetness) but do not experience flavor and thus we cannot identify many popular foods. You can easily replicate an experiment conducted by Mozel et al. (1969) by doing the following: Ask for a volunteer (ideally one with no food allergies) who isn't squeamish about tasting a variety of foods while blindfolded (and with a plugged nose). Implore your class to be quiet (you can show them cue cards with the correct answer during each guess), and then present the subject with a variety of foods that he or she should try to correctly identify without the sense of smell. For best results, food should be cut into small, uniform bite-size pieces and placed on toothpicks (you might need to help guide the food into subjects' hands). Without smell, subjects will have a surprisingly hard time identifying (or distinguishing between) foods with similar textures such as carrots, onions, pears, apples, squash, and potatoes.

Adapted from Fantino, B. F. (1981). Taste preferences: Influence of smell and sight. In L. T. Benjamin & K. D. Lowman (Eds.), *Activities handbook for the teaching of psychology* (pp. 29-30). Washington, DC: American Psychological Association.
Mozell M. M, Smith B. P., Smith P. E., Sullivan, R. L., Jr., & Swender, P. (Eds.)(1969). Nasal chemoreception in flavor identification. *Archives of Otolaryngology, 90*, 367-373.

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Activity 3.17 - The Effect of Visual Cues on Taste

Our sense of taste depends not only on olfactory cues but also on visual cues. To illustrate this fact, have a volunteer wait in the hall while you prepare (in full view of your class) a "typical American meal." Start by placing a bagel (or piece of bread) on a plate and by pouring a glass of orange juice and a glass of milk. Prepare the meal by using food coloring to distort its appearance. For example, you might make the milk a vibrant green, the orange juice look like motor oil (by mixing red, green, blue, and yellow), and the bread look moldy (with blue or green spots). Instruct your class to be a quiet audience and not to giggle or to give anything away. Bring the volunteer, blindfolded, back into the class and ask him or her to comment on the meal (e.g., "Does it taste good?" "Do you know what it is?") while eating it. The volunteer will no doubt correctly identify the foods and confirm that they taste good. After a few minutes, remove the blindfold and observe the volunteer's reaction. Asking the volunteer to continue eating will likely result in an emphatic, "No Thanks!" This should spark a lively discussion of the role of vision in taste and students are usually happy to share their personal experiences.

Adapted from Fantino, B. F. (1981). Taste preferences: Influence of smell and sight. In L. T. Benjamin & K. D. Lowman (Eds.), *Activities handbook for the teaching of psychology* (pp. 29-30). Washington, DC: American Psychological Association.

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Activity 3.18 - Saliva and Taste

Students may be surprised to learn that food must be dissolved in water in order to be tasted. That is, some kind of liquid must be available to bind solid food to the appropriate taste receptor (e.g., sweet, sour, bitter or salty). John Fisher suggests a simple exercise that demonstrates the crucial role of saliva in taste. First, have students wipe their tongue dry (the drier, the better) with the back of their hand. Then, walk around the room with a bowl of sugar and have students take a small pinch and place it on the tip of their tongue. They should not be able to taste anything until their mouth gradually moistens—with renewed saliva, the familiar sweet taste should come flooding back.

Fisher, J. (1979). *Body magic*. Briarcliff Manor, NY: Stein and Day.

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Activity 3.19 – Let Them Eat Jellybeans!

Students usually aren't aware that the sense of taste determines only roughly half of what we consider to be flavor. Flavor is, in fact, a combination of taste and smell. The demonstration outlined here, adapted from The University of Chicago's "Brain Benders," provides an excellent illustration of this. The direct link to Brain Benders is: http://mps.uchicago.edu/docs/reports07/BrainBenders.pdf

Give each of your students a jellybean (or two, or three). Ask the students to pinch their nose closed when they first place the jelly bean in their mouth. After they have chewed the jellybean with their nose plugged, ask them to unplug their noses and notice the difference. They will then be able to perceive much more of the flavor of the jellybean and be much more likely to be able to identify the flavor.

At first (when the nose is plugged), students may be able to tell that the jellybean is sweet or sour, but upon unplugging the nose the full flavor of the jelly bean emerges -- the brain is now receiving signals from both the tongue and nose. It combines the two and BOOM -- you get full *flavor*. In the brain, nerve signals from the tongue and nose are combined to produce the flavor of the jellybean. When the nose is pinched, the strict taste properties (i.e., sweet, salty, sour, or bitter) of the jellybean are apparent. But you couldn't tell the full flavor until the receptors in the nose could send nerve signals to the brain.

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Activity 3.20 - The Body's Sensitivity to Touch

Although the skin senses in general are remarkably sensitive, various parts of the body differ greatly in their sensitivity to pressure. This is because larger portions of the cerebral cortex are devoted to body areas that, for adaptive reasons, show greater sensitivity. (For example, crucial human features such as the mouth, face, and fingers are much more sensitive than are important, but less central, features such as the legs, feet, and back.) Both John Fisher and James Motiff have suggested exercises to illustrate this phenomenon. For this demonstration, divide students into pairs and have them take turns experiencing the vast differences in touch sensitivity on different parts of their body.

In Motiff's version, one student in the pair should keep his or her eyes closed while the other person randomly presses from one to four fingers lightly on that person's back, neck, leg, shoulder, forearm, face, and hand. The person being touched should attempt to guess in each case the number of fingers being applied. Students will have a much easier time correctly identifying the number of fingers applied to especially sensitive areas (such as the face and hand) compared to the other, less sensitive areas, which will feel indistinguishably like one point of pressure (i.e., one finger).

In Fisher's version, distribute a single hairpin to each pair of students. One student should pry the hairpin apart (so that its prongs are roughly an inch apart) and press the hairpin against the back of their partner's forearm. The person being touched will report feeling only a single point of pressure. Next, the student should bend the prongs inward so that they are only about 1/16 of an inch apart and place it this time on their partner's index finger tip. This time (despite the smaller difference between the prongs), the partner will have no trouble differentiating the two points, as the fingertip is much more sensitive than the forearm. For an eerier demonstration, Fisher suggests dragging the hairpin (with prongs one inch apart) slowly from the crease of the elbow down to the finger tips. Although the spacing between the prongs remains constant, the person being touched will report that distance between the prongs increases the closer the hairpin gets to the fingertips.

Finally, a demonstration suggested by Douglas Chute and Philip Schatz nicely illustrates that not all body locations receive the same attention from the brain. For this demonstration you'll need a ballpoint pen and volunteers with bare feet. First, ask students to close their eyes and hold out one of their hands. Explain that you will touch the tip of the pen to each of the three middle fingers (i.e., ignoring the thumb and the pinkie), and after each touch the student should report which finger was touched. Do this about 7-10 times, varying which finger gets touched. To no one's astonishment, students should be spectacularly successful in knowing which finger received the stimulation on each trial. Next, ask students to doff their shoes and socks, and repeat the demonstration, this time touching the three middle toes (i.e., ignoring the big toe and the littlest toe). Have students "number" their toes (big=1, next=2, littlest=5, and so on), and again report which toe was touched by the pen tip on each trial. You should now find that students are spectacularly unsuccessful at indicating which toe received the stimulation on each trial. The explanation for these differences lies in neural organization. The sensorimotor strip is dedicated much more heavily to the fingers, which receive a lot more stimulation, do a lot more work, and are a lot more important to a variety of tasks than are the toes.

Chute, D. L., & Schatz, P. (1999). Observing neural networking *in vivo*. In L. T. Benjamin, B. F. Nodine, R. M. Ernst, and C. B. Broeker (Eds.), *Activities handbook for the teaching of psychology (Vol. 4*). Washington, DC: American Psychological Association.
Fisher, J. (1979). *Body Magic*. Briarcliff Manor, NY: Stein and Day.
Motiff, J. P. (1987). Physiological psychology: The sensory homunculus. In V. P. Makosky, L. G. Whittemore, & A. M. Rogers (Eds.), *Activities handbook for the teaching of psychology: Vol. 2* (pp. 49-50). Washington, DC: American Psychological Association.

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▼ HANDOUT MASTERS

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Handout Master 3.1 Beware of What You Wish For

Human beings do not have the most sensitive or acute sensory systems in the animal world. Some bats can hear frequencies that exceed 100,000 Hertz, dolphins receive auditory messages from great distances, and cats can probably localize sounds better than we do because they can rotate their ears. Rats see better at night than we can, eagles have more acute distance vision, and horses have a wider visual field. Rabbits have more taste buds than we do, and many animals have a keener sense of smell.

This exercise asks you to consider how you would perceive the world if your senses were more acute or sensitive than they actually are.

1. List a few things you would see, that you cannot see now, if your sense of vision were "better."

2. List a few things you would hear, that you cannot hear now, if you could hear "better."

3. If your chemical senses--taste and smell--were more sensitive, how might you be affected?

4. Why are our senses no more and no less acute or sensitive than they are?

5. If human beings continue to be urban creatures for the next few million years, in what ways might our sensory systems evolve or change?

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Handout Master 3.2 Sensation

Sensation is initiated by the physical stimuli that surround and inhabit the body. As stimuli impinge on receptors, neural impulses are initiated and speed along specific pathways toward destinations in the brain. During sensation assorted influences come into play; the intensity of stimulation, its repetitiousness, and the range and mixture of stimuli. Stimulation may be subliminal, may produce sensory adaptation, or may be less than optimal. Below, explain the phenomenon being described in terms of the concept listed after it.

1. Different portions of the body vary in their sensitivity to touch. The fingertips and lips are especially sensitive and the lower back is relatively insensitive. The brain itself is completely indifferent to touch.
   Distribution of receptors:

2. Janet has prepared three cups of coffee but can't recall how much sugar is in each. The cup with the smallest amount of sugar is easy to identify, but Janet can't taste any difference between the other two cups even though she knows one has more sugar.
   Difference threshold:

3. A nurse notices that patients perform more poorly on auditory tests--tests involving the threshold of hearing--when they are tired as a result of loss of sleep.
   Signal detection theory:

4. John is looking all over for his glasses when his wife points them out at the top of his head.
   Sensory adaptation:

5. Bill was initially delighted to land a job at the post office, but recently he has become worried. By the end of his shift, he almost always feels edgy, nervous, and confused. This is difficult for Bill to understand because his work makes few demands. He just sits there all day, alone in a room, putting thousands of letters into the numerous bins.
   Optimal levels of stimulation:

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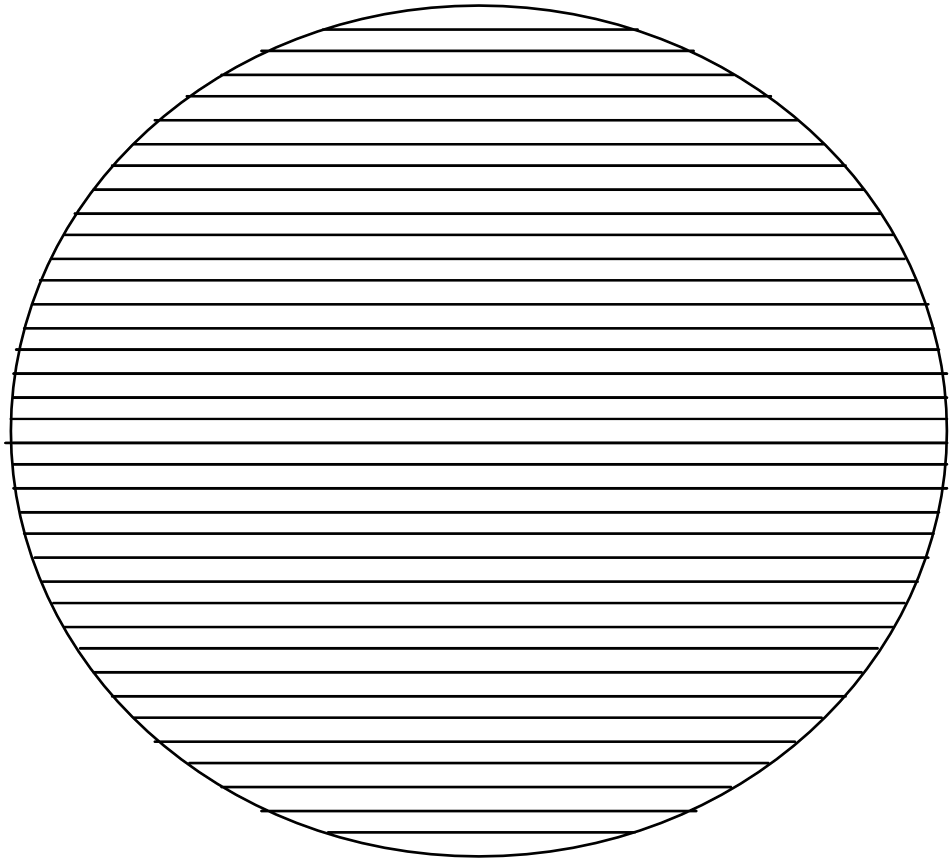
Handout Master 3.3 **The Diagonal Line Effect**



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▼REVEL Multimedia Resources

More than 5,000 Revel instructors are connecting and sharing ideas. They're energizing their classrooms and brainstorming teaching challenges via Pearson's growing network of faculty communities. The Revel community is an open, online space where members come together to collaborate and learn from each other. If you're currently teaching with Revel or considering Revel for use in your class, we invite you to join the Revel community.

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Chapter 3 REVEL Multimedia Content available:

Video: Sensation and Perception
Video: The Visible Spectrum
Video: Inattentional Blindness
Video: Recognizing Faces
Video: Perceptual Magic in Art
Video: Sensory Misconceptions
Video: Biology of Pain

Interactive: Inanimate Face Perception
Interactive: The General Process of Sensation
Interactive: Major Structures of the Eye
Interactive: The Structures of the Retina
Interactive: Monocular Cues to Depth
Interactive: Major Structures of the Ear
Interactive: Headphones and Hearing
Interactive: Taste Receptors
Interactive: Receptors for Smell

Thinking Critically Journal Writing Prompts 3.1 – 3.4

Shared Writing Prompt: Most people like the smell of wintergreen in candies, room fresheners, or nature. But when told it is the scent of an industrial solvent, some are actually sickened by the smell. Throughout this chapter you have read about instances like this one in which the very same sensory experience—the smell of wintergreen, the appearance of a multicolored dress, the taste of cilantro—can produce very different perceptual consequences in different people. Or even different outcomes for the same person in different contexts or at different points in time. Using one of these (or other) examples, discuss how biological, psychological, and cultural factors play a role in these varied perceptual outcomes.

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▼MyPsychLab Multimedia Resources

MyPsychLab features a variety of content to enhance your course. To access these resources, go to www.MyPsychLab.com, and select **Videos**, **Simulations**, or **Writing Space**.

Chapter 3 Videos

Video: The Basics: In Full Appreciation of the Cookie (4:34)
Watch how the simple act of eating a chocolate chip cookie involves all of our senses, and several parts of the brain are involved in forming our perception of that experience.

Video: The Big Picture: Taking in the World Around Us (3:50)
Learn about transduction, sense organs, and how our actions and high-level thinking begin with sensations and perceptions.

Video: In the Real World: Managing Pain (6:40)
See how injury is communicated to the brain, how pain signals can be intensified or blocked, and what the safest, most effective methods are for pain management.

Video: Special Topics: Recognizing Faces (4:33)
Find out which regions of the brain are involved in facial recognition and why some people have problems recognizing faces.

Video: Thinking Like a Psychologist: Can Smells Alter Mood and Behavior? (6:49)
Learn how smells can spark vivid memories and have a powerful effect on our mood, both good and bad.

Video: What's In It For Me? Perceptual Magic in Art and Movies (7:45)
Investigate the ways in which artists play on and exploit sensation and perception to create works of art and illusion.

Chapter 3 Simulations

Simulation: Ambiguous Figures
View ambiguous figures, and find out if what you "see" can be influenced by what you've viewed previously.

Simulation: Weber's Law
Experience the "just noticeable difference" phenomenon firsthand.

Simulation: Müller-Lyer Illusion
Test your perceptions of an optical illusions to learn about the difference between sensation and perception.

Writing Space

Writing Practice prompts within Writing Space offer immediate automated feedback. Each student submission receives feedback based on the following characteristics: Development of Ideas, Organization, Conventions, Voice, Focus and Coherence. Instructors can provide additional feedback and can adjust the auto-generated grade.

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▼Practice Quizzes and *Test Yourself* Answer Keys

Quiz for Module 3.1

1. c; 2. b; 3. d; 4. a; 5. d

Quiz for Module 3.2

1. b; 2. d; 3. a; 4. d; 5. a

Quiz for Module 3.3

1. c; 2. b; 3. d; 4. b; 5. a.

Quiz for Module 3.4

1. a; 2. c; 3. a; 4. b; 5. d.

Chapter 3 Quiz

1. c; 2. a; 3. c; 4. a; 5. d; 6. a; 7. b; 8. c; 9. b; 10. d;
11. a; 12. d; 13. d; 14. b; 15. c; 16. a; 17. b; 18. d; 19. d; 20. b.

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