Chapter 6: Sensation

A. Behavior requires the use of senses to understand and react in the world around us

I. Sensory Processing

*The two classes of experience:

A. Sensation—the detection of the elementary properties of a stimulus
B. Perception—the detection of the more complex properties of a stimulus, including its location and nature; involves learning

C. Transduction—the conversion of physical stimuli into changes in the activity of receptor cells of sensory organs

1. The brain knows what is going around in the environment by using the sense organs as information
2. Transduction is the process which takes the physical stimuli from the environment and translates it into neural activity
3. Receptor cell—a neuron that directly responds to a physical stimulus, such as light, vibrations, or aromatic molecules
   a. These cells release neurotransmitters that affect the rate of firing of neurons

D. Sensory Coding

1. If action potentials are all the same, how are we able to distinguish from so many different stimuli?
2. Anatomical Coding—a means by which the nervous system represents information; different features are coded by the activity of different neurons
   a. Although all neurons send the same signal, not all neurons send signals to the same parts of the brain
   b. The brain uses anatomical coding to interpret the location and type of sensory stimulus according to which incoming nerve fibers are active
3. Temporal Coding—a means by which the nervous system represents information; different features are coded by the pattern of activity of neurons
   a. The brain can determine a particular type of stimulus by timing amount of time in between action potentials
   b. Temporal coding is able to tell the brain how intense of a stimulus the organism is experiencing
   c. For example, a soft touch to the knee would produce a moderate amount of firing of signals as opposed to a hard touch to the knee in which the rate of firing has increased

E. Psychophysics—a branch of psychology that measures the quantitative relation between physical stimuli and perceptual experience

1. Principle of the Just-Noticeable Difference (jnd)—the smallest difference between two similar stimuli that can be distinguished
   a. It is the smallest change in magnitude that person can detect
   b. For example, an experimenter would give a person a 40 gram weight and a 41 gram weight and ask which was the heavier mass. Most people could not tell the difference (1 in 40 ratio)
   c. Psychologically this meant that a person would not be able the difference between an 80-82 gram mass or a 400-410 gram mass
   d. Weber fractions—the ratio between a just-noticeable difference and the magnitude of a stimulus; reasonably constant over the middle range of most stimulus intensities
   e. Gustav Fechner used this concept of jnd and was able to construct a graph (found on pg. 157 figure 6.2)
   f. From this graph we can derive some major concepts:
      i. The x-axis is fairly objective
      ii. The y-axis is fairly subjective
      iii. As one traces the distance between dots on the x-axis one realizes that the distance increases. This can be explained because the amount of physical energy necessary to produce a jnd increases with the magnitude of the stimulus
      iv. The shape of the curve is one that closely resembles a logarithmic function
2. Signal-detection Theory—a mathematical theory of the detection of stimuli, which involves discriminating a signal from noise in which it is embedded and which takes into account subjects’ willingness to report detecting the signal
   a. Much of psychology is based on a threshold, a thin line between perceiving and not perceiving
      i. Difference threshold—minimum detectable difference between two stimuli
ii. Absolute threshold—minimum intensity of a stimulus that can be discriminated from no stimulus at all
   b. An absolute threshold is when participants detect the stimulus 50% of the time while a difference threshold is any value below that
c. “Noise” refers to other events besides the stimuli in question during an experiment
d. Signal detection theory takes into account our willingness to report detecting a signal
e. At some point in an experiment, the participant is not sure of whether or not he/she can distinguish the stimulus at which point response bias can have an effect
f. (pg. 158 figure 6.3) describes the terminologies/possibilities in judging the presence or absence of a stimulus
g. Note that signal transduction theory emphasizes that perceptual experience involves factors other than the activity of the sensory systems

II. Vision
A. Light
   1. Our eyes can only detect the “visible light” portion of the electromagnetic spectrum (about 400-700 nm)
B. The Eye and Its Functions
   1. The eye is made up of the cornea, the transparent tissue covering the front of the eye, the sclera, the tough outer “white” layer of the eye and the iris, the pigmented muscle of the eye that controls the size of the pupil
   2. The curvature of the lens of the eyes causes images to be focused on the retina. Changes in the shape of the lens to adjust for distance is known as accommodation
   3. Sometimes the shape of the eye is not well enough that they require glasses or contact lenses to correct for them
      a. Nearsightedness-the light focuses in front of the retina. They have trouble seeing far away. To correct this we use a concave lens
      b. Farsightedness-the light focuses in the back of the retina. They have trouble seeing things up close. To correct this, we use a convex lens
   4. Embedded in the retina are photoreceptors that transduce light into neural activity
   5. The photoreceptors send information to optic neurons to the optic disk and join the optic nerve
   6. Lens-an actual lens at the front of the eye-discovered by Christopher Scheiner by looking through an ox’s eye (first suggested by Kepler)
   7. The retina is made up of:
      a. Ganglion Cell Layer-light passes through here-receives info from photoreceptors
      b. Bipolar cells (middle)
      c. Receptor layer-respond to light and sends information to bipolar cells through means of neurotransmitters. This information travels to the ganglion cells to the optic nerve (brain)
      d. The image on the retina is upside down and reversed. The brain then corrects this as it takes in the input
         i. Two types of photoreceptors-6 million rods and 6 million cones-rods function in dim light, cannot tell the difference between colors. Cones function when illumination is higher and respond to higher color different cones send signals to a single ganglion cell via bipolar cells
         ii. Fovea-small pit in the back of the retina that contains only cones. Responsible for the highest acuity-most sensitive vision
C. Transduction of Light by Photoreceptors
   1. Vitamin A is vital to the transduction of light (carrots are good for the vision)
   2. Photopigment-two part molecule that stimulates the photoreceptor-sends signals to bipolar cells-ganglion-brain
   3. Photopigments have characteristic colors-eyes turn more “pink” when exposed to less light
D. Adaptation to light and Dark
   1. Dark adaptation-process by which your adapt eyes to darkness
   2. Iris opens up-light strikes “rhodopsin” molecules which allow rods to become sensitive to light
   3. When we go from a bright spot to a dark spot, the amount of rhodopsin molecules that have been broken is not enough to send action potentials to the brain. However, once the rhodopsin molecules regenerate we are able to see again
E. Eye Movements
   1. 3 Types of Movements: saccadic, vergence, pursuit movements
F. Color Vision

1. 3 types of cones-each corresponds to different wavelengths of light
2. Dimensions of Color
   a. Wavelength-hue-perceptually
   b. Intensity-brightness-amounnt of light present
   c. Purity-saturation-number of wavelengths present
3. Additive Color Mixing
   a. Vision synthesizes-we see different types of light
   b. Passing white light through a prism creates a spectrum, passing a spectrum through a prism again produces a white light
   c. Mixing two colors “takes away wavelengths”, creates a darker color, mixing two different wavelengths of light creates a lighter color
4. Color Coding in the Retina
   a. In 1802, Thomas Young proposed a trichromatic theory in which he hypothesized that the eye contains three types of color receptors each sensitive to a different wavelength
   b. In actuality, the human eye contains three types of photopigments each of which preferentially absorbs light of a particular wavelength: 420 nm (blue-violet), 530 nm (green), and 560 nm (yellow-green)
   c. The eye works like a color television screen but in reverse. When we see white light, it stimulates the all three types of cones equally. Likewise, yellow would stimulate red and green cones to give a pure yellow color
   d. Furthermore, our eyes use two types of ganglion cells to encode for color vision
      i. For example, when there is no stimulation both ganglion cells fire at a steady rate. However, once red is spotted on the retina, excitation of the red cones causes the cells to fire at a high rate. Conversely, if green is potted on the retina excitation of the green causes the cells to fire at a slower rate
      ii. Because red and green and blue and yellow have the opposite effect on rate of axon firing, the temporal coding is known as opponent process
5. Negative Afterimages-the image seen after a portion of the retina is exposed to an intense visual stimulus
   a. The reason that afterimages form is due to adaptation of the eye to different colors, and produce the other color on the ganglion cell.
6. Defects in color vision
   a. Males are affected more than females when it comes to color vision defects.
   b. Protonopia – caused by lack of photopigment in red cones – causes red to look darker than green
   c. Deuteranopia – green cones come filled with red photpigment – opposite effect
   d. Tritanopia – much rarer, affects one in ten thousand, blues appear green and yellows appear pink

III. Audition

A. Sound

1. Rhythmical pressure changes in the air are sensed by the ear. We can perceive things between 30 and 20000 hertz. We perceive sound in terms of frequency, amplitude, and timbre.
2. The Ear and its Functions
   a. The tympanic membrane (also known as the eardrum)
   b. Ossicles – three bones to which the tympanic membrane is attached. Hammer, Anvil, stirrup (malleus, incus, and stapes) are the three different ones.
   c. Cochlea – filled with liquid – receives the signals produced by the ossicles (through the anvil)
      i. The last of the ossicles (the stirrup) presses up against an opening in the membrane of the cochlea called the oval window and transmits sound vibrations into the fluid within the cochlea
      ii. The cochlea is divided up into three chambers by two membranes. The first membrane is known as the basilar membrane which contains auditory receptor cells. As the pressure of the liquid changes due to the stirrup pushing back and forth, the basilar membrane begins to vibrate
      iii. The round window provides free space for the liquid in the cochlea to move when the basilar membrane vibrates
iv. **Auditory hair cells**-transduce the mechanical energy caused by the movement of the basilar membrane into neural activity. The cells have cilia on the ends which are **embedded** on the **tectorial membrane**

v. When the basilar membrane moves, it causes the tectorial membrane to vibrate which causes the hair cells to become stretched allowing ions to move in to the cilia allowing the cells to release a neurotransmitter to be sent through the auditory nerve to the brain

B. Detecting and Localizing in the Environment

1. Pitch and Loudness
   a. Scientists thought neurons fired at the same frequency as basilar membrane
   b. However this is not the case, neurons could not fire at the same frequency as most high frequency pitches
   c. Different frequencies stimulate different auditory hair cells which allow us to hear different pitches
   d. There are specific axons that are controlled by the auditory hair cells that control the frequency of medium and high pitches
   e. Damage to hair cells causes loss of hearing certain frequencies (depending on which cells were damaged)
   f. When different regions of the basilar membrane are stimulated, the person perceives different pitches
   g. Low frequencies are detected by the fact that they vibrate the basilar membrane at the same rate as the sound which fires axons at the same rate which causes the sound to be heard. This is an example of **temporal coding**
   h. Loudness is determined by the higher rates of firing of the axons

2. Timbre
   a. Timbre is the type of overtones behind the frequency (think of the different sounds of different instruments)
   b. Timbre is decided by overtones. The frequency that we perceive is the fundamental frequency

3. Perception of Environmental Sounds
   a. The auditory system identifies particular sound sources through pattern recognition
   b. Once you hear the sound you are able to recognize its pattern. There is a specific region in the brain that recognizes these patterns

4. Recognizing the Source of a Sound
   *The two primary methods by which we judge the source of a sound are:
   a. **Relative Loudness**-mostly used in finding the location of high frequency sounds
      i. An example of relative loudness is when an explosion happens closer to your right side, your right will hear the explosion more than the left and allow us to determine the origin of the sound
      ii. The head will cast a “sound shadow” that allows the right side to hear more of the explosion
   b. **Difference in Arrival Time**-works best with frequencies around 3000 Hz
      i. Depending on where the source is positioned around your head, your eardrums will vibrate at infrequent intervals to better detect where they are coming from

IV. **The Chemical Senses**

A. We have two senses specialized for detecting chemicals in our environment: taste and smell (they are referred to as the **chemosenses**)

B. **Gustation**-the sense of taste

1. Taste is the simplest of the senses. Do not mistake taste for flavor. Flavor combines both the taste and smell senses to produce the richness it what we taste as food
2. Taste Receptors and the Sensory Pathway
   a. Taste begins at the tongue
   b. The tongue has a bumpy appearance (the bumps are called papillae)
   c. Each papilla contains numerous **taste buds**, small organs on the tongue that contain a group of gustatory receptor cells
   d. The gustatory receptor cells then receive food that has been partially broken down by saliva and are stimulated
   e. The receptor cells then form synapses with the dendrites of neurons that send axons to the brain through three cranial nerves
3. The Five Qualities of Taste
   a. Gustation helps us determine the nature of things we put into our mouth including sourness, sweetness, saltiness, bitterness, and umami, the taste sensation that identifies amino acids
   b. Sweetness usually means that the item is packed with sugars for energy which means it is safe to eat
   c. Saltiness receptors usually tell the organism that the food they are eating has a lot of sodium chloride. Too much of this mineral can cause increased blood pressure and other negative outcomes
   d. Umami is the taste of amino acids which are necessary for survival. They create a good taste in our mouth so that we will ingest more of it
   e. Soursness and bitterness are commonly avoided because both imply that the food in which we are eating has either spoiled or is toxic to us

C. Olfaction - the sense of smell
   1. Odors have a powerful ability to evoke emotions and memories because it is connected to the limbic system
   2. Olfaction is an analytical sensory modality
   3. Anatomy of the Olfactory
      a. The receptor cells are found in the olfactory mucosa, patches of mucous membrane on the roof of the mouth. These cells have axons that form synapses with the olfactory bulbs
      b. Olfactory bulbs - stalklike structures located at the base of the brain. They perform the first analysis of olfactory information
      c. When a molecule of an odorous substance fits a receptor molecule located on the cilia of a receptor cell, the cell becomes excited. The excitation is passed on to the brain by the axon of receptor cell
      d. The olfactory sends information to the limbic system rather than the thalamus
   4. Dimensions of Odor
      a. There are several hundred receptor molecules in the olfactory system which detect different categories of odors
      b. The reason that so few receptors can detect so many different odorants is because a particular odorant binds to more than one receptor and produce different patterns of activity in different glomeruli

V. The Somatosenses
A. These include the body’s ability to react to touch, pain, vibration, warmth, coolness, limb position, muscle length and stretch, tilt of the head, and changes in the speed of head rotation
B. The Skin Senses
   1. The entire surface of the body is supplied with nerves by the dendrites of neurons that transmit somatosensory information to the brain
   2. The most common type of skin sensory receptor is the free nerve ending which infiltrate the middle layers of both smooth and hairy skin and surround hair follicles in hairy skin
   3. The largest specialized skin receptors are called the Pacinian corpuscles which are very sensitive to the touch
   4. Touch and Pressure
      a. Touch is light contact of the skin while pressure is more forceful contact that causes the skin to bend
      b. The ability to sense which part of the body is being touched varies across the body
      c. The most common method of telling touches apart is called the two-point discrimination where a person touches another person with one or both legs of a caliper. The father apart the legs of the caliper are before the person reports feeling two separate sensation the lower the sensitivity of that region of the skin
   5. Temperature
      a. There are many different thermoreceptors on the skin that allow us to feel a range of temperatures
   6. Pain
      a. There appear to be at least three types of pain receptors
      b. One type of receptor responds to intense pressure that might be caused by striking, stretching, or pinching of the skin
      c. The second type appears to respond to extremes of heat
      d. Another type contains receptors sensitive to ATP which is released when the blood supply to a region of the body is disrupted or when a muscle is damaged
      e. Pain involves complex sensory stimulation as well as emotions
      f. Pain, or fear of pain is one of the most effective motivators of human behavior
g. An interesting form of pain sensation occurs when a limb has been amputated. Amputees feel as though their limb still exists and that it hurts. This is known as **phantom limb**

C. The Internal Senses
   1. Muscles contain special sensory receptors that allow us to feel certain sensations (pangs of hunger, warm drink descending into our stomach)

D. The Vestibular Senses—account for our balance
   1. The **vestibular apparatus** of the inner ear provides sensory input to our balance along with our eyes
   2. Three **semicircular canals** located in the inner ear detect changes in the rotation of the head
   3. Another set of inner ear organs called **vestibular sacs** which contain crystals of calcium carbonate. When the head tilts the weight of the crystals shifts causing hair cells in which the sacs are connected to feel different forces and we are able to determine where we are in balance