Sensation and Perception

Sensation vs. Perception

- Sensation: aligns with **transduction** – the conversion of physical, electromagnetic, auditory and other information from our internal and external environments to electrical signals in the nervous system.
    - Performed by receptors in the PNS which then forward the stimuli to the CNS in the form of action potentials and neurotransmitters
    - Thought of as a raw signal that is unprocessed until it reaches the CNS
- Perception: processing of information to make sense of its significance
    - Manipulations include both external sensory experience and internal activities of the brain and spinal cord.

Sensory Receptors

- Neurons that respond to stimuli and trigger electrical signals
    - Distal stimuli: originate outside of the body. These are a part of the outside world
    - Proximal Stimuli: directly interact with and affect the sensory receptors
        - Informs the users about the presence of distal stimuli
    - E.g. – Camp fire is a distal stimulus while the photons that reach the observer's eyes are a proximal stimulus
- Psychophysics: relationship between the physical nature of stimuli and the sensations/perceptions that they evoke
- Signals from these stimuli must pass through specific sensory pathways in order to inform the CAN
    - Different types of receptors receive the stimulus and transmit the data to the CNS. These are usually nerve ending or specific sensory cells
    - Ganglia: collection of neuron cell bodies found outside of the CNS
- Once transduction occurs, the electrochemical energy is sent along neural pathways to various **projection areas** in the brain
- Many different sensory receptors in the body, the most commonly tested are:
    - Photoreceptors: respond to electromagnetic waves in the visible spectrum
    - Hair Cells: respond to movement of fluid in the inner ear structure (hearing)
    - Nociceptors: respond to painful or poisonous stimuli (somatosensation)
    - Thermoreceptors: respond to changes in temperature (thermosensation)
    - Osmoreceptors: respond to the osmolarity of the blood
    - Olfactory Receptors: respond to volatile compounds (smell)
    - Taste Receptors: respond to dissolved compounds (taste)

Thresholds

- Perception and sensation are closely tied to the biology and physiology of interpreting the world around us.
    - Perception is linked to experience and both internal/external biases and is thus considered apart of psychology
- Threshold: the minimum amount of stimulus that renders a difference in perception

Absolute Threshold

- Minimum stimulus energy that is needed to activate a sensory system
- This is a threshold in sensation and not in perception
- All human sensory systems are sensitive, but they have a minimum sensory level at which a smaller stimulus will not be transduced to the CNS
- How bright, loud or intense a stimulus must be before it is sensed

Threshold of Conscious Perception

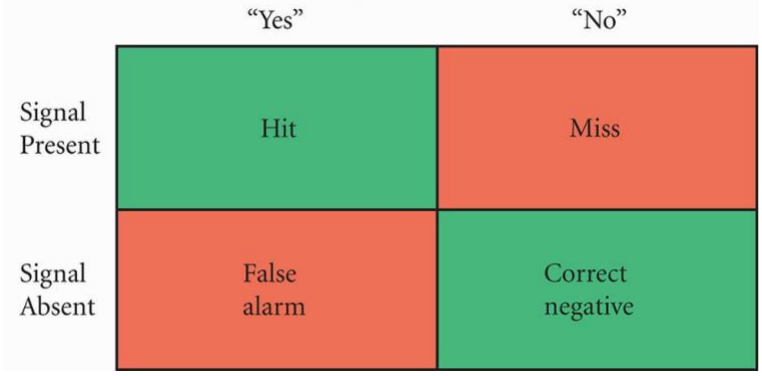
- Thresholds can be called **limina**
- Subliminal perception: refers to the perception of a stimulus below a given threshold
- A stimulus below the absolute threshold will not be transduced and thus never reach the CNS. However, a stimulus below the threshold of conscious perception arrives at the CNS, but does not reach the higher-order brain regions that control attention and consciousness
- **Discrimination Testing** (psychophysical discrimination testing) is a way to analyze the limit in human perceptive ability.
    - Participant is presented with a stimulus that is varied slightly, then participant is asked to identify whether there is a difference
    - This difference is increased until the participant notices a change

Difference Threshold or Just-Noticeable Difference (jnd)

- The minimum difference in magnitude between two stimuli before one can perceive the difference.
    - E.g. – jnd of sound frequencies is 3 Hz
- Weber's Law: states that there is a constant ratio between the change in stimulus magnitude needed to produce a jnd and the magnitude of the original stimulus
    - For higher magnitude stimuli, the actual difference must be larger to produce a jnd

Signal Detection Theory

- Stimuli perception can be affected by non-sensory factors such as memory, motives and expectations.
- Theory focuses on the changes in our perception of the same stimuli depending on both internal (psychological) & external (environmental) context
- Allows for the exploration of **response bias**: the tendency of subjects to systematically responds to a stimulus in a particular way due to non-sensory factors
- Typical experiment consists of many trials.
    - Catch Trials: stimulus is presented
    - Noise Trials: signals are not presented
    - Significant number of misses or false alarms gives an indication of response bias



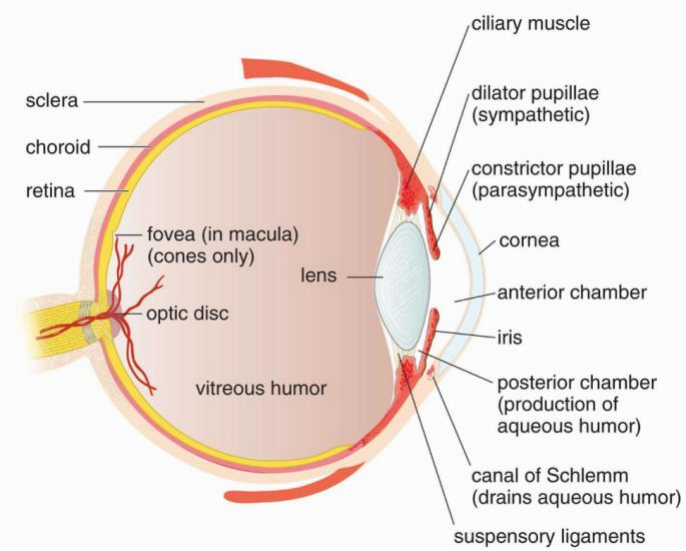
Adaptation

- Can have both a physiological (sensory) and a psychological (perceptual) component.
    - E.g. – dilation of pupils in the dark, or contraction of ear muscles to reduce ear vibration
- Can also adapt to somatosensory stimuli
    - E.g. – cold water doesn't seem so cold once you get used to it
- Adaptation is a way for the body to focus attention on only the most relevant stimuli.

Vision

Structure and Function of the Eye

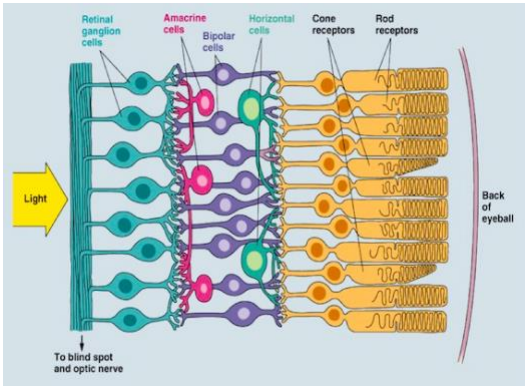
- Specialized organ used to detect light in the form of photons
- Sclera: the white of the eye. This covers the exposed portion of the eye and is a thick structural layer
    - Does not cover the cornea
- Supplied by two sets of blood vessels:
    - Choroidal Vessels: complex intermingling of blood vessels between the sclera and the retina
    - Retinal Vessels
- Retina: the innermost layer of the eye and this contains the actual photoreceptors that transduce light into electrical information that the brain can process.
    - Acts like a screen consisting of neural elements and blood vessels
    - Functions to convert incoming photons of light to electrical signals
    - Considered as part of the CNS and is an outgrowth of the brain tissue
    - Duplexity (duplicity theory of vision): states that the retina contains two kinds of photoreceptors
        - One set of photoreceptors for light and dark detection
        - One set of photoreceptors for color detection
- Light first passes through the **cornea** (clear, domelike window in the front of the eye)
    - Gathers and focuses the incoming light
- Front of eye is divided into the **anterior chamber** (in front of the iris) and the **posterior chamber** (between the iris and the lens)
- Iris: colored part of the eye that is composed of two muscles:
    - Dilator pupillae: opens the pupil under sympathetic stimulation
    - Constrictor pupillae: constrict the pupil under parasympathetic stimulation
- Iris and the ciliary body are continuous with the **choroid**
    - **Ciliary body** produces the **aqueous humor** (bathes the front part of the eye)
        - This humor drains into the **canal of Schlemm**
- Lens: Controls the refraction of incoming light and lies directly behind the iris.
- Ciliary Muscle: a component of the ciliary body and is under parasympathetic control
    - As muscle contracts, it pulls on **suspensory ligaments** and this changes the shape of the lens. This is known as **accommodation**.
- Vitreous**:** Transparent gel that lies behind the lens and supports the retina



Retina

- Retina is made up of 6 million cones and 120 million rods
- Cones: used for colour vision and to sense fine details.
    - These are most effective in bright light.
    - Come in three forms, and the forms are named after the wavelength of light that they best absorb: **S** (blue)**, M** (green)**, L** (red)
- Rods: more functional in darkened conditions. Only allow for sensation of light and dark
    - Contain single pigment that is called **rhodopsin**
    - Low sensitivity to detail and not involved in colour vision
- Most cones are concentrated in the central portion of the eye (called the **macula**)
    - Fovea: centermost point of the retina that contains only cones
        - Visual acuity is best here and is the most sensitive to daylight division

Connection between Rods and Cones

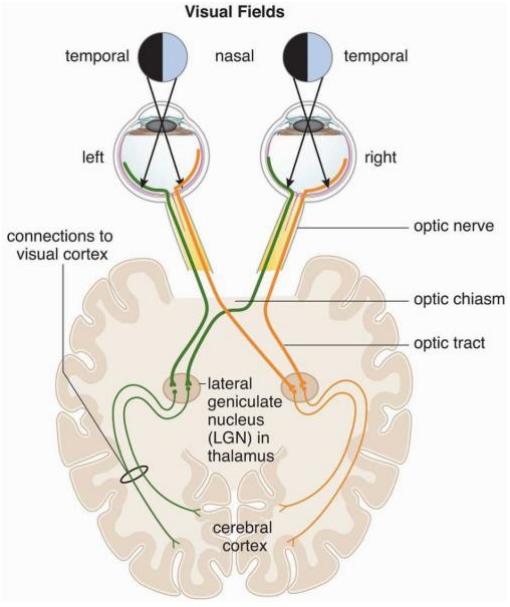


- Bipolar Cells: connect with rods and cones. These highlight the light gradient between adjacent rods or cones
- Ganglion cells: where bipolar cells synapse to. These group together to form the **optic nerve**.

- Amacrine & Horizontal Cells: receive input from multiple retinal cells from the same area. These accentuate any slight differences between the information in each bipolar cell, before the input is passed to the ganglion cells
    - Important for edge detections since they increase perception of contrasts.
- The bipolar, horizontal, amacrine and ganglion cells fall in between the rods/cones and the optic nerve
    - Information is transmitted in a "forward" direction towards the lens from the rod and cone cells
- There are many more receptors than ganglion cells, so one ganglion cell must take input from multiple rods and cones
    - Results in a loss of detail since information from the photoreceptors is combined
    - As number of receptors per ganglion cells increase, the resolution decreases
    - Usually, the number of cones converging on a cell is smaller than for rods
        - Results in colour vision having greater sensitivity to fine detail.

Visual Pathways

- Both the physical anatomical connections between the eye and brain and the flow of visual information through these connections
- Each eye's right visual projects onto the left half of each eye's retina and vice versa
- First major event occurs at the optic chiasm: fibers from the nasal half of each retina cross paths
    - Fibers carry the temporal visual field from each eye
- Temporal fibers carry the nasal visual field. These fibers do not cross the chiasm
    - Thus, **all fibers corresponding to the left visual field from both eyes projects onto the right side of the brain**, vice versa is also true.
- Reorganized pathways are called **optic tracts** (once they leave the optic chiasm)
- Information travels to several different places of the brain after it crosses the optic chiasm:
    - Lateral geniculate nucleus (LGN): located in the thalamus
    - Visual Cortex: Found in the occipital lobe. The information reaches this portion of the brain by radiating through the temporal and parietal lobes
    - Superior Colliculus: controls some responses to visual stimuli, and is involved in reflexive eye movement.



Processing

- Parallel Processing: the ability to simultaneously analyze and combine information regarding colour, shape and motion.
    - Helps in creating a cohesive image of the world as seen through the eyes
    - Features can then be compared with memories to determine what is being viewed
- Neuroscience has a similar concept to parallel processing called **feature detection**.
- Visual pathway contains cells that are specialized in detection of colour, shape and motion

Colour

- Cones are responsible for colour vision

Shape

- Detected by **parvocellular cells**. These have high color **spatial resolution**, which permits them to see very fine detail when an object is thoroughly examined.
    - Can only work with slow or stationary object since they have low **temporal resolution**

Motion

- Detected by **magnocellular cells**. These cells have very high temporal resolution, but low spatial resolution.
    - I.e. – cannot see much of the rich detail in an object once it is in motion.

Hearing and Vestibular Space

- Ear is responsible for hearing and vestibular sense (rotational and linear acceleration)

Structure and function of the Ear

- Ear is divided into three parts: the outer, middle and inner ear
- Pinna/auricle: structure where sound wave first reaches. The cartilaginous outside part of the ear.
    - Functions to channel sound waves into the external auditory canal
- External auditory canal directs sound waves to the **tympanic membrane (eardrum)**
    - Membrane vibrates in phase with the incoming sound waves
    - Frequency of sound waves determines the rate at which the membrane vibrates
    - Louder sounds have greater **intensity** that correspond to an increased amplitude of vibration.
    - This membrane is what divides the outer ear from the middle ear
- Middle ear houses three smallest bones in the body – **ossicles**
    - These help to transmit and amplify vibrations from the tympanic membrane to the inner ear
    - Malleus (Hammer): affixed to the tympanic membrane, this acts on the incus (anvil) which then acts on the stapes (stirrup)
    - Baseplate of stapes rests on the oval window of the cochlea (entrance to inner ear)
    - Eustachian tube: connects the middle ear to the nasal cavity

        - Helps equalize pressure between middle ear and environment
- Inner ear is housed within a **bony labyrinth**: **cochlea, vestibule,** and **semicircular canals**
    - All structures are continuous with each other and are filled by **membranous labyrinth**
        - Bathed with a potassium-rich fluid called **endolymph**
        - Membranous labyrinth is suspended within the bony labyrinth by another fluid called the **perilymph**
    - Perilymph transmits vibrations from the outside world and cushions the inner ear structures.

Cochlea

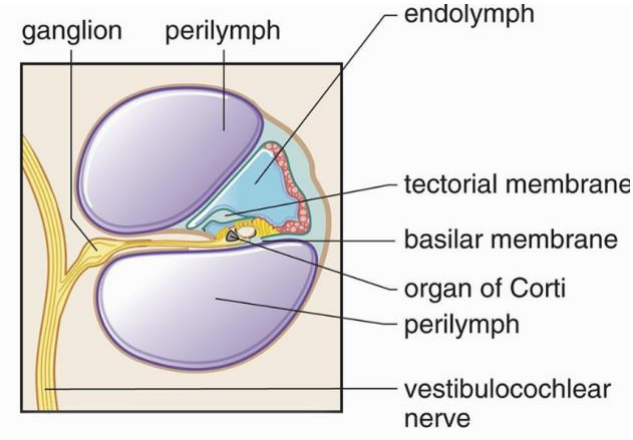
- Spiral shaped organ that is divided into three parts called **scalae**
    - Scalae run the entire length of the cochlea
- Organ of Corti: housed in the middle scala and is the actual hearing apparatus.
    - Rests on the **basilar membrane:** thin and flexible membrane
    - Consists of thousands of hair cells that are bathed in **endolymph**
    - Tectorial membrane: lies on top of the organ of Corti and is relatively immobile
- Other two scalae are filled with **perilymph** and surround the hearing apparatus
    - Continuous with the oval and round windows of the cochlea
- Sound entering the cochlea travel through the oval window, which causes vibrations in the perilymph, these are transmitted to the basilar membrane
- Round Window: permits the incompressible fluids to move within the cochlea
- Hair cells in the organ of Corti are what convert the physical stimulus to an electrical signal that can be carried to the CNS

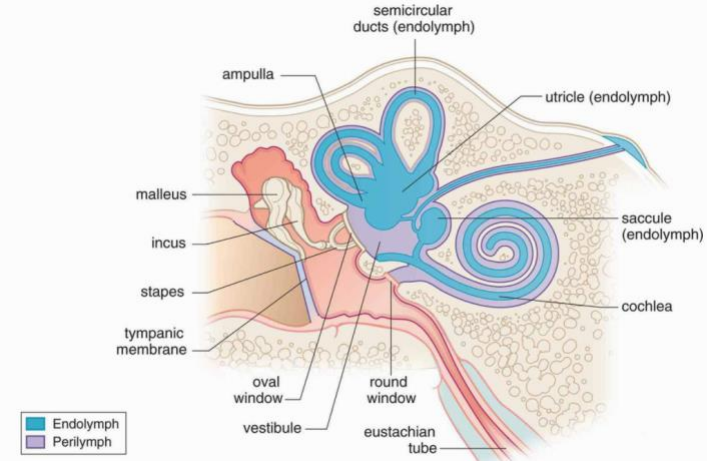
Vestibule

- The portion of bony labyrinth that contains the **utricle** and **saccule**
    - Structures are sensitive to linear acceleration and are used as part of the balancing apparatus and to determine one's orientation in 3-D space.
- Utricle and Saccule contain modified hair cells that are covered with **otoliths**
    - Otoliths resist accelerative motion which causes a bend in the underlying hair cells. The hair cells are then stimulated to send a signal to the brain

Semicircular Canals

- Three semicircular canals that are sensitive to rotational acceleration
- Arranged perpendicularly to each other and each has an **ampulla**
- Ampulla: swelling at end of semicircular canal and is where the hair cells are located.
- Similar function to vestibule, except it uses endolymph instead of otoliths and it resists rotational motion.





Auditory Pathways

- Most sound passes through the vestibulocochlear nerve and to the brainstem
- Then ascends to the **medial geniculate nucleus (MGN)** of the thalamus
- It then projects to the **auditory complex** in the temporal lobe.
    - Some information is also sent to the **superior olive:** localizes sound
    - Or to the **inferior colliculus**: involved in the startle reflex and helps keep the eyes fixed on a point.

Hair Cells

- Have long tufts of **stereocilia** on their top surface
- As vibrations reach the basilar membrane that underlies the organ of Corti, the stereocilia begin to sway back and forth within the endolymph
- Swaying causes the opening of ion channels that cause a receptor potential
- Some hair cells are connected to the immobile tectorial membrane
    - This is involved in amplifying the sound
- Place Theory: location of a hair cell on the basilar membrane determines the perception of pitch when the hair cell vibrates
    - Based on the fact that the basilar membrane changes its thickness depending on the location in the cochlea
    - Highest frequency pitch causes vibrations of the basilar membrane that is close to the oval window
    - Low frequency pitches cause vibrations at the apex (away from oval window)
    - I.e. – Cochlea is **tonotopically** organized: specified hair cells determine the pitch of the sound that the brain interprets.

Other Senses

- Hearing and vision are the most commonly tested, but other senses are still fair game

Smell

- Chemical sense: Responds to incoming chemicals from the outside world
    - Responds to volatile or aerosolized compounds
- Olfactory Chemoreceptors (nerves): located in the olfactory epithelium in the upper part of the nasal cavity.
    - Chemical stimuli must bind to their respective chemoreceptors to cause a signal
- Pheromones: ability of smell to carry interpersonal information
    - Secreted by a one person or animal and urge another to behave in a specific way
- Olfactory Pathway: odor molecules are inhaled into the nasal passage and then come into contact with olfactory nerves. Receptor cells are activated and this sends signals to the **olfactory bulb.** Signals are then relayed via the **olfactory tract** into higher regions of the brain (including the limbic system).
    - Only sense that does not pass through the thalamus

Taste

- Five basic tastes: sweet, sour, salty, bitter and *umani* (savory)
- Flavor is different from taste since it takes into account smell, texture and the mood

- Detected by chemoreceptors that are sensitive to dissolved compounds
    - Receptors are a group of cells called **taste buds**
    - These are found in little bumps on the tongue called **papillae**
- Taste information travels from taste buds to the brainstem and then ascend to the **taste center** of the thalamus before traveling to higher-order brain regions

Somatosensation

- Four components: pressure, vibration, pain, and temperature
- Have at least five different types of receptors:
    - Pacinian Corpuscles: respond to deep pressure and vibration
    - Meissner Corpuscles: respond to light touch
    - Merkle cells (discs): respond to deep pressure and texture
    - Ruffini Endings: respond to stretch
    - Free Nerve Endings: respond to pain and temperature
- Transduction occurs in these receptors; they then send the signal to the CNS where it eventually travels to the **somatosensory cortex** in the parietal lobe.
- Two-Point Threshold: minimum distance necessary between two points of stimulation on the skin so that the point will be felt as two distinct stimuli
    - Depends on density of nerves in the specified area of skin
- Physiological Zero: normal temperature of the skin
    - Temperature is judged relative to this. E.g. - Something feels "cold" if it is below.
- Gate Theory of Pain: proposes that there is a special "gating" mechanism that can turn pain signals on and off, which would affect whether or not pain is perceived.
    - Spinal cord is able to preferentially forward the signals from other touch modalities to the brain
    - Nociceptors: The most common sensory receptor for pain perception in the somatosensory system

Kinesthetic Sense or Proprioception

- Ability to tell where one's body is in space
- Receptors for this are found mostly in the muscle and joints
- Play a critical role in hand-eye coordination, balance and mobility.

Object Recognition

- Bottom-Up (data-driven) processing: object recognition by parallel processing and feature detection
    - Brain takes the individual sensory stimuli and combines them together to create a cohesive image before determining what the object is.
- Top-down (conceptually driven) processing: driven by memories and expectation that allow the brain to recognize the whole object and the recognize the components based on these expectations.
    - Allows for the quick recognition without need to analyze specific parts
- Two processing systems must both be used or else our minds would be inefficient or have difficulty discriminating between similar objects.

- Perceptual Organization: ability to use the two processes in tandem with all of the sensory clues about an object to create a complete picture or idea
- Depth Perception: relies on both monocular and binocular cues
    - Monocular cues include the relative size of objects, partial obscuring of one object by another, convergence of parallel lines at a distance, position of an object, and lighting/shadowing
    - Binocular cues are the slight difference between images projected on the two retinas, and the angle required between two eyes to bring an object into focus
- **Form** of an object is usually determined through parallel processing and feature detection. While the motion of an object is perceived through magnocellular cells
- Constancy: idea that we perceive certain characteristics of objects to remain the same

Gestalt Principles

- Ways for the brain to infer missing parts of a picture when the picture is incomplete
- Law of Proximity: elements close to one another tend to be perceived as a unit.
- Law of Similarity: similar objects tend to be grouped together
- Law of Good Continuation: elements that appear to follow the same pathway tend to be grouped together.
    - Tendency to see continuous patterns, rather than abrupt changes.
- Subjective Contours: Contours or shapes are perceived when they are not actually there. They simply fill up the space nicely
- Law of Closure: When a space is enclosed by a contour, it tends to be perceived as a complete figure
    - Also seen as the tendency to perceive some figures as being more complete/closed than they really are.
- All Gestalt principles operate to create stable, consistent and simple figure
    - These are all governed by the **law of pragnanz**
        - Perceptual organization will always be as regular, simple and symmetric as possible.