NEUROSCIENCE

5. PERCEPTION, NON-HUMAN SENSES, PYRAMIDAL SYSTEMS

5.1. The Process of Perception

Perception is the organization, identification, and interpretation of sensory information in order to represent and understand the environment. All perception involves signals in the nervous system, which in turn result from physical or chemical stimulation of the sense organs. For example, vision involves light striking the retina of the eye, smell is mediated by odor molecules, and hearing involves pressure waves. Perception is not the passive receipt of these signals, but is shaped by learning, memory, expectation, and attention. Perception involves these top-down effects as well as the bottom-up process of processing sensory input. The bottom-up processing transforms low level information to higher level information (e.g., extracts shapes for object recognition). The top-down processing refers to a person's concept and expectations (knowledge), and selective mechanisms (attention) that influence perception. Perception depends on complex functions of the nervous system, but subjectively seems mostly effortless because this processing happens outside conscious awareness.

Since the rise of experimental psychology in the 19th century, psychology's understanding of perception has progressed by combining a variety of techniques. Psychophysics quantitatively describes the relationships between the physical qualities of the sensory input and perception. Sensory neuroscience studies the brain mechanisms underlying perception. Perceptual systems can also be studied computationally, in terms of the information they process. Perceptual issues in philosophy include the extent to which sensory qualities such as sound, smell or color exist in objective reality rather than in the mind of the perceiver. Although the senses were traditionally viewed as passive receptors, the study of illusions and ambiguous images has demonstrated that the brain's perceptual systems actively and pre-consciously attempt to make sense of their input. There is still active debate about the extent to which perception is an active process of hypothesis testing, analogous to science, or whether realistic sensory information is rich enough to make this process unnecessary.

The perceptual systems of the brain enable individuals to see the world around them as stable, even though the sensory information is typically incomplete and rapidly varying. Human and animal brains are structured in a modular way, with different areas processing different kinds of sensory information. Some of these modules take the form of sensory maps, mapping some aspect of the world across part of the brain's surface. These different modules are interconnected and influence each other. For instance, the taste is strongly influenced by its odor.

The process of perception begins with an object in the real world, termed the distal stimulus or distal object. By means of light, sound or another physical process, the object stimulates the body's sensory organs. These sensory organs transform the input energy into neural activity, a process called transduction. This raw pattern of neural activity is called the proximal stimulus. These neural signals are transmitted to the brain and processed. The resulting mental recreation of the distal stimulus is the percept. Perception is sometimes described as the process of constructing mental representations of distal stimuli using the information available in proximal stimuli. An example would be a person looking at a shoe. The shoe itself is the distal stimulus. When light from the shoe enters a person's eye and stimulates their retina, that stimulation is the proximal stimulus. The image of the shoe reconstructed by the brain of the person is the percept. The different kinds of sensation such as warmth, sound, and taste are called sensory modalities.

Psychologist Jerome Bruner has developed a model of perception. According to him, people go through the following process to form opinions:

1. When we encounter an unfamiliar target we are open to different informational cues and want to learn more about the target.
2. In the second step we try to collect more information about the target. Gradually, we encounter some familiar cues which help us categorize the target.
3. At this stage, the cues become less open and selective. We try to search for more cues that confirm the categorization of the target. We also actively ignore and even distort cues that violate our initial perceptions. Our perception becomes more selective and we finally paint a consistent picture of the target.

According to researchers Alan Saks and Gary Johns, there are three components to perception:

1. **The Perceiver -** The person who becomes aware about something and comes to a final understanding. There are 3 factors that can influence his or her perceptions: experience, motivational state and finally emotional state. In different motivational or emotional states, the perceiver will react to or perceive something in different ways. Also in different situations he or she might employ a perceptual defense where they tend to see what they want to see.
2. **The Target -** This is the person who is being perceived or judged. "Ambiguity or lack of information about a target leads to a greater need for interpretation and addition."
3. **The Situation -** Also greatly influences perceptions because different situations may call for additional information about the target.

5.2. Senses

A broadly acceptable definition of a sense would be a system that consists of a group of sensory cell types that responds to a specific physical phenomenon, and that corresponds to a particular group of regions within the brain where the signals are received and interpreted. There is no firm agreement as to the number of senses because of differing definitions of what constitutes a sense. The traditional senses are sight, hearing, taste, smell, and touch. They are outlined below;

1. **Sight or vision** - Is the capability of the eye(s) to focus and detect images of visible light on photoreceptors in the retina of each eye that generates electrical nerve impulses for varying colors, hues, and brightness. There are two types of photoreceptors: rods and cones. Rods are very sensitive to light, but do not distinguish colors. Cones distinguish colors, but are less sensitive to dim light.
2. **Hearing or audition -** Is the sense of sound perception. Hearing is all about vibration. Mechanoreceptors turn motion into electrical nerve pulses, which are located in the inner ear. Since sound is vibrations propagating through a medium such as air, the detection of these vibrations, that is the sense of the hearing, is a mechanical sense because these vibrations are mechanically conducted from the eardrum through a series of tiny bones to hair-like fibers in the inner ear, which detect mechanical motion of the fibers within a range of about 20 to 20,000 hertz, with substantial variation between individuals. Hearing at high frequencies declines with an increase in age. Inability to hear is called deafness or hearing impairment.

3. **Taste** (or, the more formal term, **gustation**) - Is one of the traditional five senses. It refers to the capability to detect the taste of substances such as food, certain minerals, and poisons, etc. The sense of taste is often confused with the sense of flavor, which is a combination of taste and smell perception. Flavor depends on odor, texture, and temperature as well as on taste. Humans receive tastes through sensory organs called taste buds, or gustatory calyculi, concentrated on the upper surface of the tongue.
4. **Smell** or **olfaction** is the other "chemical" sense. Unlike taste, there are hundreds of olfactory receptors (388 according to one source), each binding to a particular molecular feature. Odor molecules possess a variety of features and, thus, excite specific receptors more or less strongly. This combination of excitatory signals from different receptors makes up what we perceive as the molecule's smell. In the brain, olfaction is processed by the olfactory system. Olfactory receptor neurons in the nose differ from most other neurons in that they die and regenerate on a regular basis. The inability to smell is called anosmia.
5. **Touch** or **somatosensory -** Also called tactition or mechanoreception, is a perception resulting from activation of neural receptors, generally in the skin including hair follicles, but also in the tongue, throat, and mucosa. A variety of pressure receptors respond to variations in pressure (firm, brushing, sustained, etc.). The touch sense of itching caused by insect bites or allergies involves special itch specific neurons in the skin and spinal cord. The loss or impairment of the ability to feel anything touched is called tactile anesthesia.

5.3. Non-Human Senses

Senses are physiological capacities of organisms that provide data for perception. The senses and their operation, classification, and theory are overlapping topics studied by a variety of fields, most notably neuroscience, cognitive psychology (or cognitive science), and philosophy of perception. The nervous system has a specific sensory system or organ, dedicated to each sense. Humans have a multitude of senses. Sight (ophthalmoception), hearing (audioception), taste (gustaoception), smell (olfacoception or olfacception), and touch (tactioception) are the five traditionally recognized. While the ability to detect other stimuli beyond those governed by the traditional senses exists, including temperature (thermoception), kinesthetic sense (proprioception), pain (nociception), balance (equilibrioception), and various internal stimuli (e.g. the different chemoreceptors for detecting salt and carbon dioxide concentrations in the blood), only a small number of these can safely be classified as separate senses in and of themselves. What constitutes a sense is a matter of some debate, leading to difficulties in defining what exactly a sense is.

Animals also have receptors to sense the world around them, with degrees of capability varying greatly between species. Humans have a comparatively weak sense of smell, while some animals may lack one or more of the traditional five senses. Some animals may also intake and interpret sensory stimuli in very different ways. Some species of animals are able to sense the world in a way that humans cannot, with some species able to sense electrical and magnetic fields, and detect water pressure and currents. Other living organisms have receptors to sense the world around them, including many of the senses listed above for humans. However, the mechanisms and capabilities vary widely. Most non-human mammals have a much keener sense of smell than humans, although the mechanism is similar. Sharks combine their keen sense of smell with timing to determine the direction of a smell. They follow the nostril that first detected the smell. Insects have olfactory receptors on their antennae. Flies and butterflies have taste organs on their feet, allowing them to taste anything they land on. Catfish have taste organs across their entire bodies, and can taste anything they touch, including chemicals in the water. Cats have the ability to see in low light, which is due to muscles surrounding their irises, which contract and expand their pupils, as well as to the tapetum lucidum, a reflective membrane that optimizes the image. Pit vipers, pythons and some boas have organs that allow them to detect infrared light, such that these snakes are able to sense the body heat of their prey. The common vampire bat may also have an infrared sensor on its nose. It has been found that birds and some other animals are tetrachromats and have the ability to see in the ultraviolet down to 300 nanometers. Bees and dragonflies are also able to see in the ultraviolet.

In addition, some animals have senses that humans do not, including the following:

Echolocation

Certain animals, including bats and cetaceans, have the ability to determine orientation to other objects through interpretation of reflected sound (like sonar). They most often use this to navigate through poor lighting conditions or to identify and track prey. There is currently an uncertainty whether this is simply an extremely developed post-sensory interpretation of auditory perceptions or it actually constitutes a separate sense. Resolution of the issue will require brain scans of animals while they actually perform echolocation, a task that has proven difficult in practice. Blind people report they are able to navigate and in some cases identify an object by interpreting reflected sounds (especially their own footsteps), a phenomenon known as human echolocation.

Electroreception

Electroreception (or **electroception**) is the ability to detect electric fields. Several species of fish, sharks, and rays have the capacity to sense changes in electric fields in their immediate vicinity. Some fish passively sense changing nearby electric fields; some generate their own weak electric fields, and sense the pattern of field potentials over their body surface; and some use these electric field generating and sensing capacities for social communication. The mechanisms by which electroceptive fish construct a spatial representation from very small differences in field potentials involve comparisons of spike latencies from different parts of the fish's body. The only orders of mammals that are known to demonstrate electroception are the dolphin and monotreme orders. Among these mammals, the platypus has the most acute sense of electroception. A dolphin can detect electric fields in water using electroreceptors in vibrissal crypts arrayed in pairs on its snout and which evolved from whisker motion sensors. These electroreceptors can detect electric fields as weak as 4.6 microvolts per centimeter, such as those generated by contracting muscles and pumping gills of potential prey. This permits the dolphin to locate prey from the seafloor where sediment limits visibility and echolocation.

Magnetoception

Magnetoception (or magnetoreception) is the ability to detect the direction one is facing based on the Earth's magnetic field. Directional awareness is most commonly observed in birds. It has also been observed in insects such as bees. Although there is no dispute that this sense exists in many avians (it is essential to the navigational abilities of migratory birds), it is not a well-understood phenomenon. One study has found that cattle make use of magnetoception, as they tend to align themselves in a north south direction. Magnetotactic bacteria build miniature magnets inside themselves and use them to determine their orientation relative to the Earth's magnetic field. The question of how useful magnetoception may be to human beings is subject of ongoing research.

5.4. Neural Pathways

Pyramidal system – Direct Activation Pathway

All of the motor impulses that orginate at the cortical level (in cortex of brain) travel through this tract. This pathway supplies the voluntary muscles of the head, neck, and limbs. Neurons of this tract originate in the post-central gyrus or primary motor cortex. The pyramidal system has two tracts: corticospinal and corticobulbar. The nerve fibers of the corticospinal tract travel down through the internal capsule down to the medulla. At the inferior level of the medulla, 70-90% of the nerve fibers on each side will deccusate, or cross over to the other side. Those that cross over continue down the spinal cord and are collectively known as the lateral corticospinal tract, and these fibers exert contralateral control. The remaining 10-30% travel down the ipsilateral side and are collectively known as the ventral corticospinal tract, and these fibers exert ipsilateral control. These will continue to travel down the spinal cord until they reach the level of the muscles they will serve, where they will then synapse with the nuclei of lower motor neurons. The nerve fibers of the corticobulbar tract initially follow the same pathway as the corticospinal tracts. However, these will begin to synapse with the motor nuclei of the cranial nerves beginning at the level of the upper pons. These fibers will deccusate at various levels of the brainstem. Of interest is that the nuclei of the facial nerve receive bilateral innervation for some muscles and unilateral representation for others. Generally speaking, the upper face is more bilaterally innervated, and the bottom half is more unilaterally innervated (but by contralateral fibers).

Extrapyramidal System – Indirect Activation Pathway

In anatomy, the extrapyramidal system is a neural network that is part of the motor system that causes involuntary reflexes and movement, and modulation of movement (i.e. coordination). The system is called "extrapyramidal" to distinguish it from the tracts of the motor cortex that reach their targets by traveling through the "pyramids" of the medulla. The extrapyramidal system works by modifying neural impulses that originate in the cerebral cortex. Impulses generated at the primary motor strip are sent via the extrapyramidal fibers to the basal ganglia. In a complex network of pathways, the structures of the basal ganglia modify impulses and send information to each other. Some fibers will then be directed down to synapse with the lower motor neurons. Other fibers are routed through the thalamus and back up to the cortex. The role of the extrapyramidal system includes the following: (1) selective activation of movements and supression of others (2)

Initiation of movements (3) setting rate and force of movements (4) coordinating movements. Damage to the extrapyramidal system, but especially damage to the basal ganglia, will result in movement disorders known as dyskinesias. Different types of dyskinesias include:

- **Myoclonus** - Characterized by involuntary single or repetitive jerks of a body part. If the jerks are repetitive, they can be rhythmic or non-rhythmic. They can be isolated to one muscle group or a number of muscles at the same time. These movements can occur spontaneously, but also to stimuli (visual, tactile or auditory). Hiccups are a form of myoclonus (brief spasm of diaphragm.).
- **Tics -** These are rapid, repeatingly coordinated or patterned movements that are under partial control by the affected person. Often, the person will relate that they have an irresistible urge to perform the movements. They can often suppress the movements temporarily. Simple tics may appear similar to dystonia or myoclonus. Complex tics are coordinated and can involve jumping, noises, lip smacking, and other rapid, repeated movements.
- **Chorea** - Characterized by rapid, involuntary, random, purposeless movements of a body part. Can be present at rest, during sustained postures, and during movement.
- **Ballism** - Characterized by gross, abrupt contractions of axial and proximal muscles of the extremities that can produce flailing.
- **Athetosis** - A relatively slow, writhing, purposeless movement of a body part. Athetosis and choreaic movements often combine with each other, and called choreoathetosis. Athetosis is a major category of the effects of Cerebral Palsy.
- **Dystonia -** A slow form of hyperkinesia characterized by involuntary abnormal postures resulting from excessive co-contraction of antagonistic muscles. Writers’ cramp is a form of this.
- **Spasm -** A general term that designates a variety of muscular contractions. Tonic spasms are prolonged. Clonic spasms are repetitive, have a rapid onset, and are brief.
- **Tremor** - Rhythmic (periodic) movement of a body part. Resting tremors occur when a body part is at rest. Postural tremor occurs when the body part is maintained against gravity. Action tremor occurs during movement. Terminal tremor occurs as the body part nears a target.