

Chapter 1

Introduction

Most of us take for granted our ability to perceive the external world. However, this is no simple deed at all. Imagine being given a task of designing a machine that can perceive, locate, describe and identify all the objects in the environment and their relationship with each other. Such a machine is yet to be realized. However, humans and animals have solved this problem in an seemingly effortless manner. Because of this ease, with which we perceive the environment around us, often we do not realize the complexity and the importance of the feat achieved.

1.1 The Perceptual Process

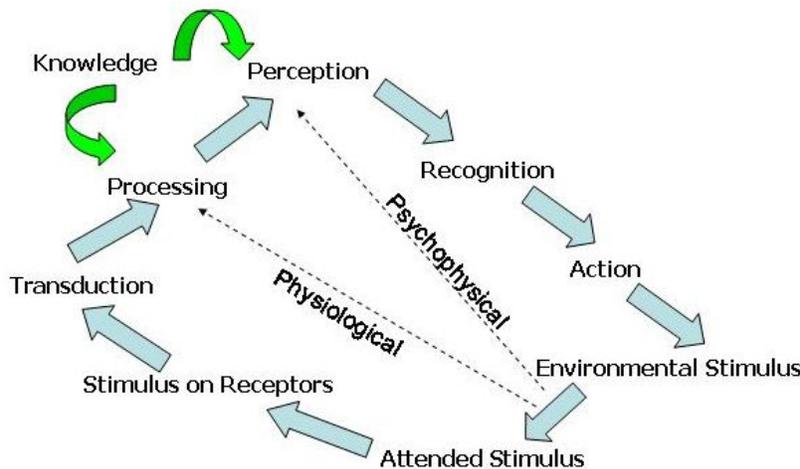


Figure 1.1: The Perceptual Process

First, let us introduce the perceptual process. This process is diagrammed in Figure 1.1 as a sequence of steps starting from the environment to the perception of a particular stimuli, recognition of the stimuli and action with regard to the stimuli. We will do this with an example. Let us take an example of Mary who has just arrived at the circus.

The environmental stimulus is defined as all the things in our environment that we can *potentially* perceive. In our example, as Mary takes her seat, she observes everything around her: an animal act going on in the center stage, a few clowns in the side, the audience around her, the trapezes hanging from the ceilings and the music band on the right. These form the environmental stimulus.

Next, Mary focuses her attention to something that she finds particularly interesting, for example the animal act going on in the center stage. This is called *attended stimulus*.

When Mary focuses her attention on the animal by looking directly at it, a image of the animal is formed on the receptors of the retina of the eye. This defines the *stimulus on the receptors* stage.

Transduction is the process of transformation of one form of energy to another. For example, when you press any button on the bank teller machine, the pressure produced by your finger is transduced to electrical energy. Similarly, in the nervous system, when environmental energy is transformed to electrical energy, it is called transduction. In our example, this occurs when the stimulus on the receptors are transformed into electrical signals.

These electrical signals generate new signals in the cells of nervous system called neurones. This process is called *neural processing*.

Perception can be defined as a conscious sensory experience. When the electrical signals produced by the neurones are somehow processed by the brain and converted to the experience of seeing the animal, the stimulus is said to be perceived.

The next two processes, recognition and action are not exactly perception. They are perceptual behaviors that are important outcome of perceptual process. *Recognition* is our ability to place a object in a category. For example, Mary is at this point identify the animal to be a tiger. Though it may be tempting to believe that perception and recognition happen together, it has been shown that they are different. *Action* includes the motor activities such as moving the eyes or moving the body in response to the process of perception. Almost always an action involves movement of the eye, which changes the attended stimulus and the whole cycle repeats.

Knowledge has a role to play in the ability of an individual to recognize different objects, events or situations. For example, using previously acquired and stored knowledge of different animals, Mary is able to identify the animal in the center stage as a tiger. Thus, knowledge is involved while perception and triggers recognition.

The inclusion of knowledge in this cycle enables us to distinguish between two types of perceptual processing.

- When the process starts from the stimulus on receptors and goes towards perception, it is bottom up processing.
- The process that starts with the knowledge that a person brings to an environment is a top down processing.

We will see in the rest of the course, that perception often involves both of these working together.

1.2 Visual Perception

There are several sense which help us to perceive the world around us. These include seeing, hearing, touching, tasting and smelling. There are some creatures for whom nonvisual senses play the dominant role. For example, bats use there audio perception for navigation. However, for humans and for most other species, vision plays the most important role. Vision has evolved in these animals to provided successful means of survival and reproduction. It is through vision that one can achieve desirable objects like nutritious food, warm shelter and strong mates. It also provides important cues against dangers like predators and falling objects.

The primary advantage of vision, which is probably the reason for its evolution as the preeminent vehicle of perception, is that it provides accurate information from a distance. The sense of hearing and smelling can provide information from a distance, but may not be very accurate. At the same, tasting and touching can provide accurate information, but only on contact. Thus, vision provides, what we call *veridical perception* (in Latin *veridicus* means *truthfully*) consistent and accurate with the actual state of the environment without being in contact with the environment. Though there are a small number of pathological cases when this is not true, but for amazingly large number of situations, by and large, *what we see is what we get*.

In the context of this course, *visual perception* is defined as the process of acquiring knowledge about our environmental objects and events by extracting information from the light they emit or reflect. Note that visual

perception involves acquisition of knowledge. This means that it is a cognitive activity and is not merely an optical process. This is the different between human vision and cameras. Cameras can take pictures but do not *know* anything about the scenes/objects they capture. Cameras can merely capture *information*, but humans and animals can additionally *acquire knowledge* from this captured information.

1.3 Studying the Perceptual Process

There are primarily two different ways to study the perceptual process. In the first, we study how the person's perception is related to the stimulus. Here we do not consider the details of *how* this perception was really arrived at. This is called *psychophysical analysis* of the perceptual process. The second way to study it is to consider how the person's perception is related to the physiological processes that are occurring within the person's sensors and/or brain. This is called *physiological analysis* of the perceptual process. Both of these are indicated in Figure 1.1. In both these, we will also be concerned with the role of knowledge (includes also memories, expectations etc) in perception. This is called *cognitive influences*. However, note that all these are intimately related and often we will take a more holistic approach of cross referencing these disciplines and forming a complete and consistent picture of the perceptual procedure.

1.3.1 The Psychophysical Approach

The relationship between stimulus and perception can be measured in three different ways. There are two ways of measuring it qualitatively. These are *description* and *recognition*. In the descriptive way, the subject is asked to describe a perception. In recognition, the subject is presented with a stimulus and asked to recognize. Both of these are heavily used by doctors in treating patients. However, with the goal of studying perception, what we are more concerned with is a quantitative way of measuring the relationship, through *detection, magnitude* and *search*.

The method of detection was first proposed by the famous scientist Gustav Fechner in 1860 and was later improved by scientists like Ernst Weber.

Absolute Threshold: This is defined as of the smallest amount of stimulus required to detect the stimulus. Fechner proposed three different methods to find the absolute threshold.

- *Method of Limits:* Here the subject is presented with stimulus in an ascending or descending order and the subject is asked to detect at which point the stimulus becomes detectable or undetectable respectively.
- *Method of Adjustment:* Here the subject is provided with a continuous control by which he/she can control the strength of the stimulus and then mark the point where it is barely detectable.
- *Method of Constant Stimuli:* Here the subject is presented with stimuli of random strength at random order and asked to identify if it is detectable or not. The data thus collected can be plotted to identify the range of the absolute threshold.

Difference Threshold: This was proposed by Ernst Weber. The difference threshold (DL) is defined as the smallest difference between two stimuli that a person can detect. To measure the difference threshold, a person is presented with a 'standard' stimulus S and a 'compared' stimulus C simultaneously. The difference between the strength of the 'compared' stimulus and the 'standard' stimulus is increase by increasing the strength of the 'compared' stimulus until the difference is detected by the subject.

Studying the difference threshold for various stimulus led to the discovery of a very important relationship in perception called the *Weber's Law*. This says that the ratio of the difference threshold to the standard stimulus is constant. Mathematically,

$$\frac{DL}{S} = K, \quad (1.1)$$

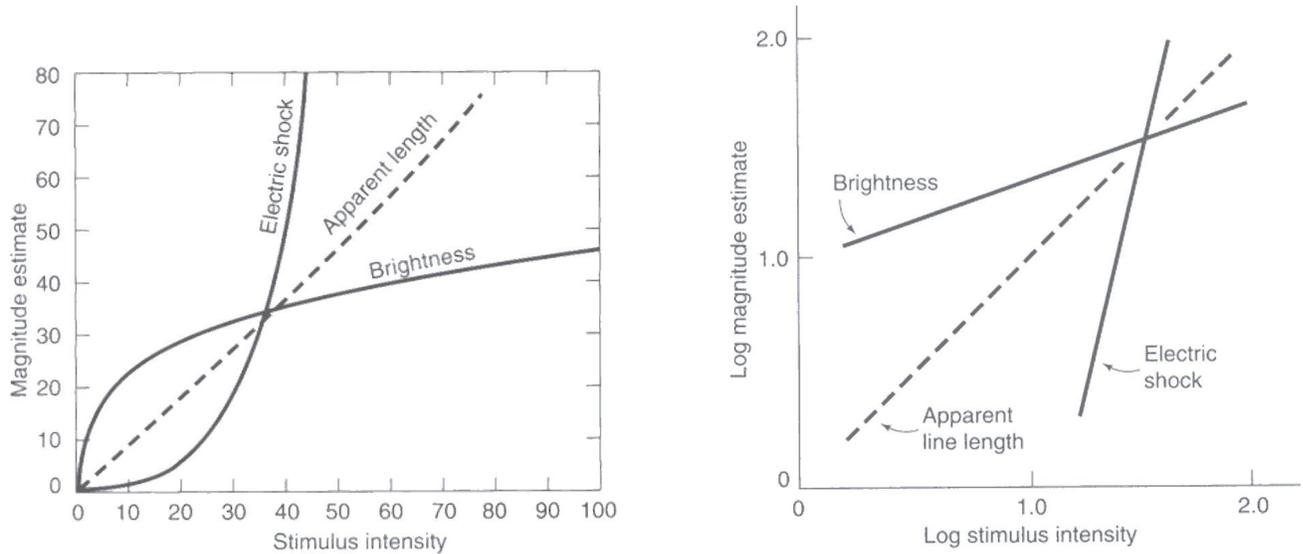


Figure 1.2: Left: Response Compression and Expansion, Right: The same response is linear in a logarithmic scale.

where the constant K is called the *Weber fraction*.

These methods of measuring thresholds tell us when a stimulus becomes detectable. But what about the above threshold perception. For example, if we double the intensity of a light, does it look doubly bright? The method of magnitude is used to study this.

Magnitude Estimation: To measure the above threshold relationship between stimulus and perception accurately, S. S. Stevens developed a method called *magnitude estimation*. In this method, the subject is presented with stimulus of different strengths, and is asked to assign a number to his perceived sensation. These numbers are plotted against the strength of the stimulus presented to get the response.

It has been found that for most sensations, doubling the stimulus does not necessarily mean doubling in the perceived sensations. Thus, the relationship between stimulus and perception is not linear. For some sensations like brightness of light, the change in the perceived sensation is less than the change in the stimulus strength. This is called *response compression*. For some other sensations like electric shock, the change in the perceived sensation is more than the change in the strength of the stimulus. This is called *response expansion*. These are illustrated in Figure 1.2. In fact, Steven discovered that for most senses, the strength of the stimulus, S , and the perceived sensation, P , is related by a power function,

$$P = KS^n, \quad (1.2)$$

where K and n are constants. $n > 1.0$ suggests response expansion and $n < 1.0$ suggests response compression. This is called *Steven's Power Law*.

Finally, the method of search involves looking for and recognizing. This can often present important insights for the relationship between stimulus and perception.

The above gives a few extensively used methods used for psychophysical experiments. But, several other methods are used or are being devised to find the relationship between stimulus and perception.

1.3.2 The Physiological Approach

Receptors in the sensory organs like eye, ear, skin etc transduce environmental energy (stimulus) into electrical signals. These signals are carried to different areas of the brain by *nerves* where they are processed to cause

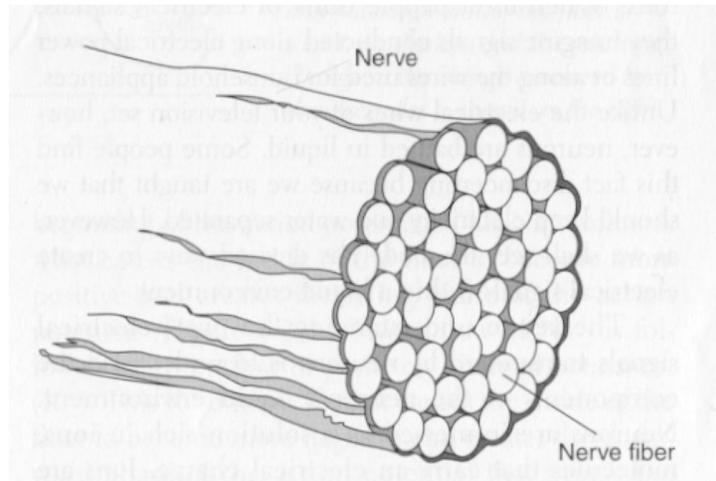


Figure 1.3: A nerve is made up of many nerve fibres.

different perceptions. This is the broad basis of the physiological approach of studying the perceptual process.

Nerves are composed of smaller structures called *neurons*. Neurons consist of

1. *Cell Body*: This contains the nucleus and other metabolic structures required to keep the cell alive.
2. *Dendrites*: This branch out from the cell body to receive electrical signals from other neurons.
3. *Axon or Nerve Fibre*: A tube filled with fluids that conducts the electrical signal.

Many such neurons combine to create a nerve. The axons form the individual components of the nerve, just like many individual wires travel within a telephone cable as shown in Figure 1.3. *Receptors* are specialized neurons that can respond to environmental stimuli like light or sound waves.

Recording of Electrical Signals in Neurons: Neurons carry electrical signal in a very different way that the wires that carry electricity to our homes. Neurons are immersed in a solution rich in *ions*, molecules that carry electrical charge. The solution outside the axon of a neuron is rich in positively charged sodium (Na^+) and the solution inside the axon is rich in positively charged potassium (K^+). These ions create electrical signals in the neuron when they flow across the axon cell membrane.

Figure 1.4 show how this happens. The example shows a pressure sensitive receptor neuron. In the normal state (not excited), a potential difference of 70 mV exists across the axon cell membrane. This is caused by the different concentration of the ions inside and outside the axon. This is called the *resting potential*.

When excited by the pressure stimulus, a rapid change in the potential occurs. It goes up rapidly to 40 mV and returns back to the resting potential, all within the very small time of 1 ms . This rapid increase in the potential is called a nerve impulse or an *action potential*. This caused by the flow of the ions across the cell membrane. The rising phase of the action potential is accompanied by a inflow of Na^+ in the axon raising its positive potential. This is followed by an outflow of K^+ from the axon which brings down the action potential back to the resting potential. This kind of flow of ions are caused by the change in *permeability* of the membrane to sodium and potassium. Permeability is a property of the membrane that refers to the ease with which molecules can pass through the membrane. When the cell is not stimulated, the permeability to sodium and potassium is low. The stimulation triggers a process by which the membrane becomes highly permeable to sodium and potassium leading to the action potential. However, the Na^+ and K^+ does not accumulate inside and outside the axon respectively. This is prevented by a mechanism called *sodium-potassium pump* which continuously returns sodium to the outside

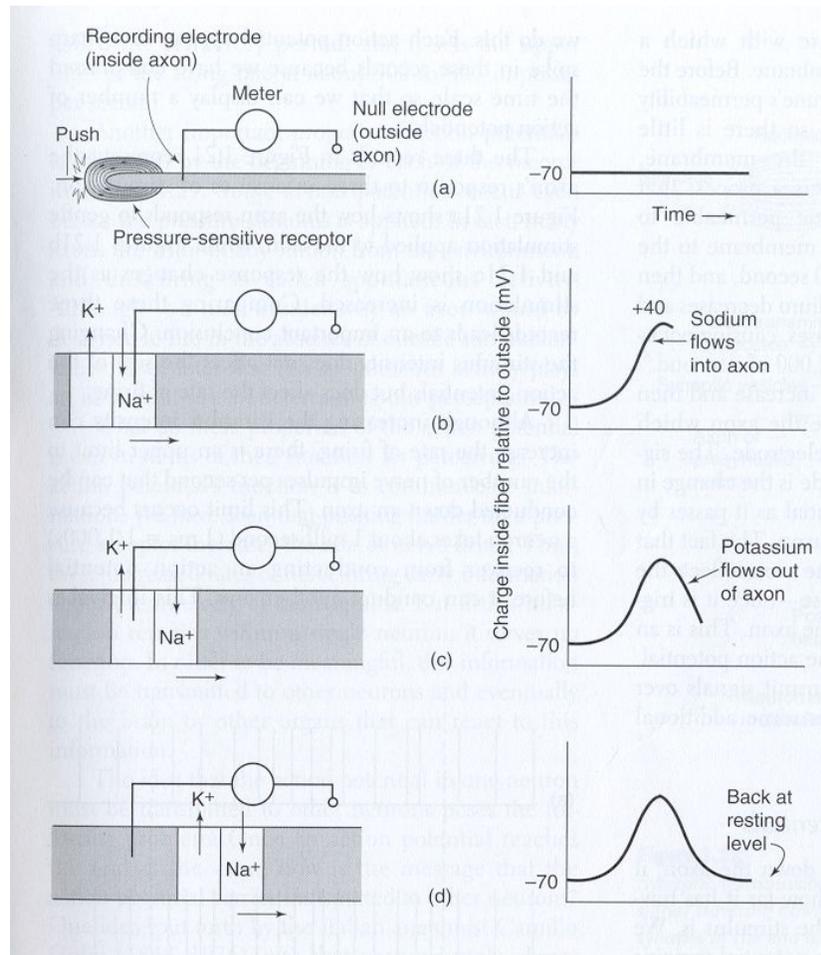


Figure 1.4: Generation of nerve impulse. As long as the fibre is at rest, there is a resting potential of -70 mV between the inside and outside of the fibre (a). As a nerve impulse is generated, an increase in potential occurs by inflow of Na^+ in the axon (b). This is followed by an outflow of K^+ from the axon that brings the potential back to -70 mV (c)(d).

and potassium to the inside of the axon at their original concentration levels so that the axon does not continue to generate nerve impulses. Next, this action potential travels all the way down the axon. This is called *propagated response*.

However, the resting potential, the action potential and the duration of the action potential is always the same. This means that the strength of the stimulus is not indicated by the magnitude of the potential. Instead, it is indicated by the rate of firing. Higher the stimulation, higher is the rate of firing. However, there is a maximum limit to the rate of firing. This is due to a *refractory period* of 1 ms after each firing when the neuron cannot fire. This sets the upper limit of the firing rate to about 800 impulses per second. Another important point to note here is that in the non-excitable state also the neurons show some minimum firing. This is called the *spontaneous activity*. This plays an important role in perception as we will find later.

Transmitting the Electrical Signal: The next question is once the action potential is transmitted through the axon as propagated response, how does it get transmitted to other neurons? The neurons are not in contact with each other. There exists a very small space between two neurons called the *synapse*. The electrical signals do not go

across this synapse. Instead they trigger a chemical activity in the synapse which is instrumental in transmitting the information from one neuron to another.

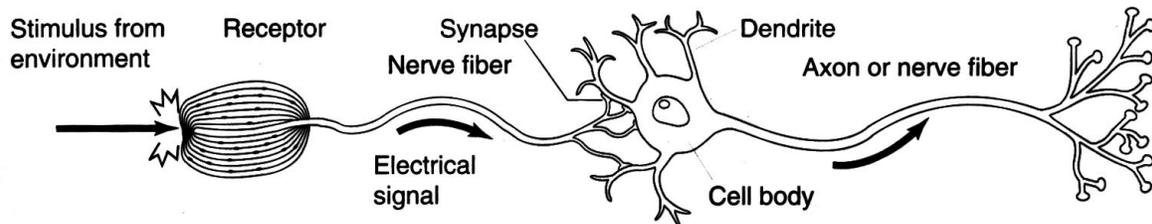


Figure 1.5: The neuron shown on the right has a cell body, dendrites and axon. A neuron that receives stimuli from the environment, shown on left, has a receptor in place of cell body.

The neuron from which is transmitting the signal is called the *presynaptic neuron* and the neuron receiving the signal is called the *postsynaptic neuron*. The *synaptic vesicles* of each neuron store some *neurotransmitters*. When the action potential reaches the end of presynaptic neuron, these vesicles release packets of neurotransmitters. These flow into small areas of the postsynaptic neuron called the *receptor sites*. Each receptor site is of different shape and sensitive to specific neurotransmitters. When the neurotransmitter makes contact with a receptor site that matches its shape, the postsynaptic neuron is triggered. However, depending on the nature of neurotransmitter and the nature of cell body, it can cause either an *excitation* (increased firing) or *inhibition* (reduced firing). The necessity of inhibition will become evident as we advance through the course. This whole process of generation and movement of electrical signal through the neurons are illustrated in Figure 1.5

Processing in Brain: Finally, the signal thus transmitted reaches the brain. The brain is still an active area of research and here we will cover whatever little we know about it. Much of the research in the connection of perception is focussed in the area of *cerebral cortex*. It is a 2 mm this layer that covers the surface of the brain and contains the machinery for creating perception, language, memory and thinking. A basic principle of cortical function is *modular organization* – specific functions are served by specific areas of the cortex.

There are different *primary receiving areas* for different senses in the brain. Each of these areas receive signals initiated by that particular sense's receptors. For example, the *occipital lobe* is the primary receiving area for vision, *temporal lobe* for hearing and *parietal area* for touch. However, advanced processing of the signals in the brain are not limited to the primary receiving areas.