UNIT 2 PSYCHOPHYSICS: THRESHOLD, SIGNAL DETECTION THEORY

Structure

2.0 INTRODUCTION

So far you have understood as to how you have sensation and perception of an object around you in the world. You are able now to distinguish between sensation and perception of an object. When stimulus is put through to a sense organ and you have a vague knowledge of presence of the stimulus, you have sensation of it. But when meaning is added to it, that is when you understand the real object, it becomes perception. You are now aware of the processes through which sensation converts into perception. But have you ever attempted to know as to how you feel different degree of sensation? For example you taste something and say 'a bitter taste'; get pressure on your body and say a 'dull pressure'; see an intense red colour and say a 'brightish red'. How have you been able to feel the different intensity of different sensations? This is interesting to know. The details of the sequence are very different for the different senses and the stimuli that normally excite them, in the receptors, in the qualities of their sensations are also different. This section of the study will help you in understanding answers of such process.

In fact, the sensory system does not respond unless the stimulus energy is above some critical level of intensity. The stimulus energy below the critical level of intensity does not produce sensation. The branch of knowledge which deals with such phenomenon is known as *psycho-physics*. You may have to be more careful in studying this section, which seems to be difficult but really *not at all* difficult to understand. You will learn in clear terms and simple language the processes of psychophysics and its different concepts. The concepts are *threshold – absolute*

threshold and *differential threshold*. The methods through which the thresholds can be determined are the method of *limits* and method *constant stimuli*. The laws which govern such phenomena include the *Weber's Law*, the *Fechner's Law*, and the *Steven's Power Law*. *Response bias* plays an important role in determination of, and response to, a sensation. *The signal detection theory* explains the impact of response bias in such sensations. This way, the finer distinction of sensation and its determination, you will be clearly in a position to understand. You will also be able to determine experimentally the intensities of sensations in comparable terms.

2.1 OBJECTIVES

After reading this unit, you will be able to:

- Define the concept of psychophysics;
- Define threshold and identify types of thresholds;
- Indicate the methods of determining the nthreshold;
- Explain Weber's Law, Fechner's Law, Steven's Power Law;
- Define response bias in determining sensations;
- Describe signal detection theory; and
- Identify signal detection and decision process.

2.2 PSYCHOPHYSICS

You have experience from different senses with details of the sequence very different from each sense but the path from stimulus to sensory experience is almost similar. Vision is different from taste or hearing but all these necessarily have three steps common in sequence, viz., (i) presence of proximal stimulus (ii) neural chain of events (nerve impulse, message to brain) and (iii) psychological response or sensation.

In this process, the message is often modified by other parts of the nervous system as well. Psychophysics studies the relationship between some property of the physical stimulus and the psychological consequence, that is sensory experience quite apart from the intervening neural steps.

The field, which tries to relate the characteristics of physical stimuli to attributes of the sensory experience they produce, is known as psychophysics.

You may easily measure the magnitude of the stimulus(physical) in terms of physical energy. For instance it can be done in kilos, in degrees centigrade, in inches, in decibels or whatever but it is difficult to measure quantitatively the psychological intensity or the magnitude of a sensation To measure magnitude of a sensation in quantitative terms several methods have been developed which are known as psychophysical methods.

2.3 THRESHOLD

The world around you provides many stimuli at a time but you do not respond to all stimuli, particularly those which are very low in intensity. Different types of

sensations need different intensity of stimuli for activation. Galanter (1962), for example, stated that we can hear a watch tick twenty feet away in a quiet room. We can detect the taste of a single tea spoon of sugar in two gallons of water. We can smell a single drop of perfume in an empty three-room apartment and on a clear dark night, we can see a dim candle thirty miles away. A question arises then that how much physical stimulation is necessary in order to experience a sensation? Normally we think that the relationship between stimulus intensity and sensation is direct , meaning that we always will have sensation when the intensity of stimulus is sufficient. But in a real life it does not happen. One reason may be that our sensitivity to external stimuli changes from moment to moment and in order to maintain the body's internal environment at optimal level the sensitivity of our sensory organs to stimuli varies. The sensory system will not respond unless the stimulus energy is above some critical level of intensity, the so-called *absolute threshold.*

Absolute threshold, therefore, is the smallest amount of a stimulus that one can detect 50% of the time.

Suppose one stimulus is presented to a person and of total number of trials the person is able to detect the stimulus 50% of the time, this point of detection is known as *absolute threshold.* This way, absolute threshold is the point where a person is able to detect the presence of the stimulus half of the times the stimulus is presented to the person.

Another point is important in sensation as to how one discriminates between two sensations. What is the minimal amount by which original intensity of a stimulus is increased so that it may have a changed sensation? Consider the sensation of visual brightness produced by a patch of light on the eye. To experience a sensation of brightness *just* greater than the previous one, how much minimal amount of light intensity patch is to be increased. Again, the changed brightness must be experienced by 50% of the times of presentation. This amount which makes a difference is called *difference threshold*. It produces a just noticeable difference, that is j.n.d. The j.n.d. indicates subject's capacity to discriminate.

The difference threshold is the amount by which a given stimulus must be increased or decreased so that the subject can perceive a just noticeable difference (j.n.d.) 50% of the times.

Take the example. You take a glass of water. You add a grain of sugar to it and ask the subject if the person is able to detect the sweetness. The response will be 'no'. Keep on adding grains to it. A point will come when the subject will say 'yes'. The *point* where the change is felt is *absolute threshold* and the *amount* added to it to feel a change to sweetness is the *difference threshold*.

2.4 PSYCHOPHYSICAL METHODS

The set of procedures through which sensory thresholds are determined is known as psychophysical methods. One method, the method of limits, works like this. Skin sensation may be determined by one apparatus aesthesiometer. It has two points which can be made longer and shorter. A particular area of hand is encircled and the two points of the apparatus is touched with equal pressure all the time.

The subject is blind folded and asked to report if it has sensation of one point or two points. Trials are taken in ascending and descending order. Ascending trials start with the presentation of the two points at minimum distance that is with sensation of touch of one point followed by increased distance between two points so that two points sensation is there.

Descending trials are taken in just opposite manner. They begin with sensation of two points followed by decrease in distance between two points of the apparatus so that the subject reports sensation of one point touch. Many trials are taken to get a correct estimate of threshold in ascending and descending order and average is taken out. It also takes into account the error of habituation and error of anticipation. A tendency, to say 'one point sensation' in ascending series and 'two point sensation' in descending series, independent of whether the subject actually feels the points, is known as the error of habituation. The people's tendency, to change response to the stimulus before actual feel of it, is known as the error of anticipation. The *point* where sensation of 'one point' converts into 'two points' sensation is the *absolute threshold*.

Another method is *method of constant stimuli.* This method is simple as well. The j.n.d. or difference threshold can be determined through method of constant stimuli. Take a set of weights with one standard stimulus and others comparison stimuli, say, 100 grams as standard stimulus and 84, 88, 92, 96 grams below the standard stimuli and 104, 108, 112, 116 grams above the standard weight as comparison stimuli. On each trial ask the subject to judge between the two weights – one standard and the other comparison ones and get response if comparison weight is lighter, equal or heavier to the standard one. Present all comparison weights with standard weight together one by one in a suitably designed manner. Finally, the number of grams that has to be added to create a just noticeable difference is found out. While conducting the experiment proper care is taken to present the comparison stimuli with the standard one in a way so that no error is effective in finding out *difference* threshold. This type of experiment can be conducted on many sensations adopting proper procedures.

These methods make assessment of psychological intensity, the magnitude of sensation, easy. It was believed by Fechner, the founder of psychophysics, that sensations cannot be compared to physical stimuli but they can be easily compared to each other. A person can compare two of his own sensations and judge whether the two are the same or different.

2.5 THE WEBER'S LAW

Gustav Theodor Fechner (1801-87), the founder of psychophysics, attempted to measure j.n.d. with a view to achieving a higher goal that is, formulation of a law relating stimulus intensity to sensory magnitude. Fechner was of the view that such a law could be built upon an empirical generalisation first proposed by E.H. Weber (1795-1878), a German physiologist, in the year 1834.

Weber gave the observation that the size of the difference threshold is proportional to the intensity of the standard stimulus. This ratio is constant. The size of the difference threshold, a constant ratio of the standard stimulus, is often referred to as *Weber Fraction*. This example will make this law more clear. Suppose that you can just tell the difference between 100 and 104 grams then you will be able

to just distinguish between 200 and 208 grams, 400 and 416 grams and so forth. Fechner labelled it as Weber's law which is algebraically put as

$DI/I = C$

Where

DI is the increment in stimulus intensity (i.e. the j.n.d.)

I is the stimulus intensity (the standard stimulus)

C is constant

Many studies were conducted in the past to see whether Weber's law holds for all of the sensory modalities. It was verified in most of the cases except a few where the nervous system geared to notice relative differences rather than absolute ones. This law allows us to compare the sensitivities of different sensory modalities. Suppose you want to know, whether eye is more sensitive than the ear. This can be seen using Weber's law. If Weber's ratio is small, the discriminative power of the sense modality is great and vice-versa. This law helps in understanding the salient features of different sense modalities. It has been found out, using this law, that humans are keen in discriminating brightness than loudness, the Weber's fraction being 1/62 and 1/11 respectively.

2.6 FECHNER'S LAW

You have seen that Weber's law postulates that the more intense the stimulus, the more the stimulus intensity needs to be increased before the person gets a change. Fechner, with a number of assumptions, generalised Weber's findings which indicated a broader relationship between sensory and physical intensity. Fechner's law stated that the strength of a sensation grows as the logarithm of stimulus intensity. The formula is

$S = K \log I$

Where S is psychological (i.e. subjective)

Magnitude

I is stimulus intensity

K is constant

Fechner's law makes good biological sense as our nervous system compress huge rage of sensation awareness into some manageable scope, and this is what a logarithmic transformation does for us.

2.7 STEVEN'S POWER LAW

You have so far come to know that area of psychophysics concerns the relationship between stimulus intensity and sensory magnitude. Fechner, extending Weber's law, believed that general equation, with logarithmic relationship, does exist that holds good for all senses.

Fechner stated that the scale of subjective sensory intensity has almost the same properties which characterize physical dimensions, the unit of subjective sensory intensity being j.n.d.

Weber's law tells us that each just noticeable stimulus increment is a constant fraction of the stimulus to which it is added. The sensations go up by an arithmetic

series and the stimuli by a geometric series, therefore, we must mark off ever-larger intervals on the physical scale to correspond to equal intervals on the psychological dimensions. Woodworth (1938) stated as follows: "the sensation plods along step by step while the stimulus leaps ahead by ratios."

Fechner's formulation was very influential but a question was there. Is it that sensory magnitude can only be assessed indirectly as Fechner had claimed? To answer this question, a Harvard Psychologist S.S. Stevens (1906-1973) provided one straight forward method. He asked subjects to estimate sensory magnitude *directly*. In his method, a series of stimuli were presented to subjects and they were asked to assign numbers that were proportional to the corresponding subjective impressions. Thus, if one tone sounds three times louder than another, the subject had to assign a number to the first that was three times larger than the number given to the second. (Stevens, 1961).

Two points were special to it. (i) The subject had little trouble in performing the task. They could judge their own subjective experience on a direct scale of subjective magnitude. (ii) The relation between this scale and physical intensity, as Stevens found out, was not logarithmic.

Hence Stevens conceived a power function, the formula being

$S = kI^N$

Where – S stands for subjective magnitude
I for stimulus intensity
k and N are constants.

This exponential function asserts that the intensity of a sensation is proportional to stimulus intensity raised to a certain power. When N is smaller than I, sensation grows more slowly than stimulus intensity and when N is larger than I, sensation grows more rapidly than stimulus intensity. Nervous system plays an important role in its compression or expansion. Let us take an example of sensation of pain by electric shock. Here the organism is better served by expansion than by compression. When the stimulus is quite intense, even a small increment in its intensity may spell difference between survival and destruction. Expansion of the subjective scale incites the victim to escape before serious harm is done. A look into the development of methods to measure sensation quantitatively from Weber to Stevens would reveal that these were great contributions to the field of Psychology. Until the middle of 19th century, scientists had despaired of ever measuring psychological processes. But Fechner showed the way and now we are in a position to measure sensation more accurately in quantitative form.

2.8 RESPONSE BIAS

You ask a person to lift different weights of different magnitude. If the difference is very little between the two weights, it will be difficult for the person to say exactly whether both are equal or one is heavier or lighter than the other. In such cases, attitudes and beliefs of the person play an important role in responses. One may say most of the time equal or heavier or lighter apart from the magnitude of the stimulus. The response is not correct in such cases, hence, real threshold cannot be found out. Always responding equal or heavier or lighter of the stimulus, although not really in sensory sensitivity, is *response bias*.

Take another example. You present a very weak tone to a blind folded subject and ask whether it is audible or not. Since the tone is very weak in magnitude, it will be difficult to take a correct decision. The person may approach the task with a free and easy attitude cheerfully offering 'yes' response, and a 'no' response following conservative line whenever in doubt. The response will depend on the attitude of the person. You, therefore, will not be able to get a correct threshold determination. Early psychophysicists tried to cope with this problem by using subjects who were highly trained observers. To find out response bias in such studies experimenters used to throw in occasional *catch trial* on which there was no stimulus at all (Woodworth, 1938). This way, this type of error in response was detected and counterbalanced.

2.9 SIGNAL DETECTION THEORY

Recent development in psychophysics takes suitably the problem of response bias attitude in sensory experience. Green and Swets (1966) described *detection experiment* on the basis of which a theory was developed known as 'signal detection theory'. This theory suggests that these are no absolute thresholds for sensations. Rather, detection of stimuli depends on their physical energy and on external factors such as the relative costs and benefits associated with detecting their presence.

Signal detection theory has a somewhat different testing technique in which catch trials are a regular part of the procedure rather than just an occasional check to keep the subjects on their toes. To know whether the subject can detect the presence of a stimulus, a fairly weak stimulus is selected and presented on half of its trials. On the other half of the trials 'no stimulus' is presented.

Both the stimuli that is the 'weak stimulus' or 'no stimulus' are presented in random order. Two kinds of errors may be committed by the subject. One is a 'miss', not reporting a stimulus when present; another is a 'false alarm', reporting a stimulus when, in fact, not present.

Two kinds of correct responses may also be given. Reporting a stimulus when it is actually present 'hit' and not reporting it when none is present 'correct negative'.

The detection experiment gives a basis for getting at the non-sensory factors underlying response bias. One is differential payoff based on 'payoff matrix'. That is , in this you pay a subject for every 'hit' and 'correct negative' and penalise for every 'miss' and 'false alarm' as per prescribed schedule of gains and losses. This is called 'payoff matrix'. The four possible outcomes of the detection experiment are:

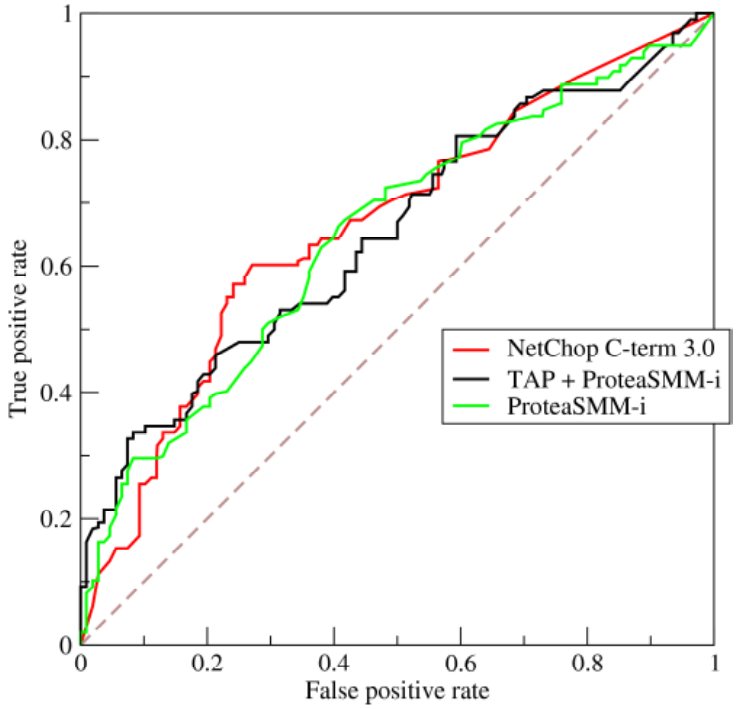
	Responds Yes	**Responds No**
Stimulus present	Hit	Miss
Stimulus absence	False alarm	Correct negative
	Subject says 'yes'	**Subject says 'no'**
Stimulus present	+10 Rs. (Hit)	– 10 Rs. (Miss)
Stimulus absence	– 1 Re. (False alarm)	+ 5 (Correct negative)

The 'pay off matrix' where the subject gains Rs. 10/- for every 'hit' and Rs. 5/- for every correct negative; loses Rs. 10 /- . for every 'miss' and Re. 1/- for every 'false alarm', This will ; will lead to a 'bias' toward 'yes' judgements. With this payoff matrix, the subject will do well to adopt a liberal criterion and give a 'yes' judgement whenever the subject is in doubt.

Take for instance an example, Suppose in such an experiment, on 50 trials the subject has no sensory information on the basis of which she can decide whether the stimulus is present or absent. If she consistently says 'yes' she will be on the average be correct on 25 trials (thus collecting Rs.250/-) and wrong on the other 25 (thus losing Rs.25/-) and her net gain will be Rs.225. In contrast, consistent 'no' judgements will lead to a net loss of Rs. 125.00 (+ Rs. 125 for the correct negative and – Rs. 250 for the false alarm). If the stimulus is presented half of the trials, the payoff bias can be calculated easily by comparing the sum of the values under the 'yes' column with the sum under the 'no' column. In the example presented, these sums are +9 Rs. and – 5 Rs. respectively. This way, the subject will adopt a liberal criterion and give 'yes' judgement even if she is in doubt.

2.10 THE ROC CURVE

With the help of the Receiver-operating-characteristic curve (ROC) sensitivity and response bias is separated. The first step in the experiment is to vary response bias while keeping sensitivity constant by changing payoff matrix. Another way is to vary the proportion of trials on which 'no stimulus' is presented – the four such trials, the greater the 'yes' bias. When subject is more conservative, thee appears a reduction in the proportion of trials on which one is guilty of false alarm. At the same time there is a reduction in the proportion of hits. This effect can be plotted of the two proportions against each other. This is ROC curve. (See the figure below)



The next step is to get the index of sensitivity which is not contaminated by response bias. For separate detection experiment separate ROC is plotted. The

stronger stimulus, the more its ROC curve is bowed away from the main diagonal. The displacement of the ROC curve from the main diagonal provides a pure measure of sensitivity for the stimulus on which the ROC curve is based; it is measured along the second diagonal.

2.11 SIGNAL DETECTION AND DECISION PROCESS

Why a person gets so much of difficulty in distinguishing between the presence and absence of a stimulus? Signal detection theory provides a satisfactory answer. This theory states that there really is no such thing as zero stimulus. It assumes that psychophysical judgements are based on some underlying neural activity to the sensory system which may vary in magnitude. Normally, it is believed that sensory process takes place by an actual external stimulus. But this theory postulates that sensation can take place even in the absence of any external stimulus due to *background factors*. Hearing, for example, can take place even if no actual sound is produced. There is spontaneous activity in the nervous system which can produce sensation of hearing. So sensation is the product of both the presentation of the external stimulus and also background factors i.e. mental states. This way, signal detection theory provides more effective explanation of sensory process and its measurement.

2.12 LET US SUM UP

You have come to know by how that the founder of psychophysics, G.T. Fechner studied sensory intensity by determining the ability of the subject to discriminate between stimulus intensities. Important measures to it are the absolute and difference thresholds. The difference threshold is the change in the intensity of a stimulus that is large enough to be detected at least 50% of the presentation. The absolute threshold is the lowest intensity of the stimulus that produces a response. Weber's law indicated that the difference threshold or the j.n.d. is a constant fraction of the intensity of the standard stimulus. Fechner explored wider relationship which states that the strength of the sensation grows as the logarithm of stimulus intensity. Stevens extended the work further and stated that it was possible for subjects to deal with sensations head-on and to scale them directly. Response bias indicated the role of attitudes and beliefs of subjects due to which subjects fluctuate in their reactions to the same physical stimulus intensity. Signal detection theory asserts that observers who are asked to detect the presence or absence of a stimulus try to decide whether an internal sensory experience should be attributed to background noise or signal added to background noise. Payoff matrix helps in determination of such situations. Decision process, according to signal detection theory, is influenced by sensory process even if there is no such thing as zero stimulus.

2.13 UNIT END QUESTIONS

1) What is psychophysics?
2) What is absolute threshold?
3) What is difference threshold and absolute threshold?

4) Weber's law is: .....

5) Fechner's law is: .....

6) Steven's law is: .....

7) What is response bias: .....

8) What is signal detection theory?

9) Payoff matrix: formulation

10) How signal detection theory helps in understanding the decision process?

2.14 SUGGESTED READINGS

Galanter, E. (1962), Contemporary Psychophysics. In R. Brown, E. Galanter, E.G. Hess & G. Mandler (Eds.), *New Directions in Psychology*. New York: Holt, Rinehart & Winston.

Green, D.M., and Swets, J.A. (1966). *Signal Detection Theory and Psychophysics*. New York: Wiley.

Woodworth, R.S. (1938), *Experimental Psychology*. New York: Holt.

Robert Sessions Woodworth (1999). *Woodworth & Schlosberg's Experimental Psychology*, Holt Rinehart and Winsoton, New York,